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ERRATA

Page 421, Line 28, last word "Economics" should read "Engineering."

Page 768, Last line under heading "Inscription on Tablet": "Horticulturists" should read "Agriculturists".

Pages 709 to 755 inclusive, first word in heading: "August" should read "July".

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A STUDY OF THE BASIC, BROMATE AND BLEND BAKING FORMULAE AS MEANS FOR DETERMINING WHEAT QUALITY, WITH PARTICULAR REFERENCE TO LOW GRADE WHEAT OF THE CROP OF 1928.*

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The terms "quality" and "strength" when applied to wheat are used rather vaguely to designate in general those characteristics which make it desirable for the purpose of milling bread flours. To the miller in Western Canada, using straight hard red spring wheat, strength means the characteristic which is expressed in the flour as ability to produce a large, light loaf of fine texture and of good color and appearance, when baked under normal conditions. It implies also the ability of the flour to produce good bread even when handled by methods which are not ideal, or in other words, the ability to withstand a certain amount of abuse. Testing wheat which is intended for domestic use resolves itself into the evaluation of the flour entirely on its own merits from the standpoint of its ultimate use for bread-making.

In Europe, Canadian wheat has, in general, a somewhat different use. There it is commonly used for blending with softer wheats in order to introduce certain desirable characteristics which are lacking in the softer wheats, or which are present to a small extent. One of the chief concerns of the European miller is the amount of this high priced Canadian wheat necessary in a given mixture to produce a flour of sufficient strength to meet the requirements of the trade. Since the bulk of our wheat crop is exported, it is a matter of some importance to consider quality of wheat from this point of view.

The testing of quality of flour in its final manufactured form is a problem distinctly different from the testing of wheat quality. In the former case it is only necessary to use a method sufficiently severe to meet the most rigorous demands of the baker, which means, in effect, ascertaining whether or not the flour comes up to a certain standard. Strength of flour above a certain limit is of little commercial use, because there is an optimum value beyond which any excess strength is of little advantage in bread production, and indeed a too great excess of strength may be a distinct disadvantage. Commercial flour testing therefore resolves itself into the application of a well defined standard. It is probably quite safe to say that the baker, both domestic and commercial, is concerned chiefly with knowing if the flour will conform to a certain requirement rather than with knowing the maximum loaf volume which could be obtained.

*This work was carried out under a grant from the Agricultural Research Foundation of Saskatchewan, and the results were presented at various times as evidence before the Royal Grain Inquiry Commission of Saskatchewan.

The testing of wheat quality presents quite a different problem. Wheat is a raw material that exhibits extremely wide variations. Obviously, in attempting to manufacture a product of definite characteristics, it is necessary to know as accurately as possible the values of the raw materials used. Therefore if hard wheat is to be used in blending, it is desirable to employ means for determining, if possible, a measure of its capacity to produce strong flour when mixed with wheat of low strength. This blending capacity must be somewhat directly related to the reserve strength which is excess over that required for production of flour of a particular standard of quality. Furthermore, it should be borne in mind, that in testing wheat by means of flour experimentally milled therefrom, one is dealing with a case which is in no wise comparable to commercial practice. The flour so obtained cannot be considered a manufactured article similar to that found on the market. It represents only one of the raw ingredients used in flour manufacture. As a case in point, consider a sample of No. 1 Northern hard red spring wheat which is to be subjected to the milling and baking test. Such wheat unmixed with lower grade wheat would rarely, if ever, be milled into flour. It would be blended, if used domestically, with lower grades of hard red spring wheat, or if used by the foreign miller, it would be mixed with softer wheats. The experimentally milled flour from the sample could scarcely be considered similar to a manufactured product of commerce. The information desired is not the degree to which it conforms to a given quality standard for flour, but rather the maximum strength obtainable with such wheat in order that an estimate may be made of its value as raw material of commerce. The methods used in making tests of wheat strength must be designed with this end in view.

The baking test most commonly used in America involves the use of flour, water, yeast, sugar and salt only. With commercially milled flours, this formula in general is quite adequate to give results which are a fair measure of the conformity of the flour to the standards required. With flours experimentally milled from high grade Canadian hard red spring wheats, it fails in most cases to give reliable information regarding the quality of the sample. Wheats grown in parts of Western Canada having the reputation for producing high strength wheat frequently, when tested by the foregoing method, give results that would classify them as very inferior. Larmour and MacLeod (*3*) have shown that such experimental flours when baked by the bromate differential test, often show very great positive responses. From the results thus obtained, they would be regarded as exceedingly high in quality. As a result of a large number of such observations, the conclusion has been reached that in testing wheats, the data obtained by use of the simple or basic formula alone may be quite unreliable. and that a method involving addition of potassium bromate or some other substance similar in effect must be used in all cases. It is believed that the latter method gives results which are fairly indicative of the strength of the wheat.

Even the use of the bromate or similar formulae may yield results that fail to give a correct measure of strength. The use of strong wheats is in mixing with weaker wheats in order to bring the quality of the blend to some definite value. The final measure of the utility of a given wheat

sample should be obtainable by determining how the flour behaves when mixed with soft wheat flour and baked. The applicability of these three baking procedures can be shown by the results of work conducted in this laboratory, with a view to determining the relative values of wheat of the different grades of the 1928 crop.

Western Canada produced in 1928 a wheat crop which was singular in several respects. Due to a protracted period of slight rainfall immediately following the seeding, growth was very uneven, and despite the occurrence of abundant precipitation during June and July, the portion which germinated last never caught up with the earlier growth. The result of this condition was that even where the crop came to normal maturity, there was an unusually large percentage of immature and green kernels present in the threshed grain.

A much more serious factor entered, however, with the occurrence during the third week of August of several nights of severe frost. The wheat over a large area was at this time well filled, and in very many cases practically ready for cutting within a few days. The consequence of this late freezing was that a large proportion of wheat when threshed was found to be frosted, but very high in test weight per bushel. Due to the uneven growth, many types of frost damage frequently occurred in grain harvested from the one field.

In grading grain therefore, two problems had to be faced, one due to the presence of green and immature but otherwise undamaged wheat, the other due to frosted wheat showing all degrees of freezing. Past experience indicated that frosted wheat is inferior to sound wheat.

Birchard (*1*) in 1920 reported that the quality of wheat is practically unimpaired when the frost is confined to "bran-frost." In case of heavy frost, the bread was found to be slightly lower in volume and darker in color than in the case of sound normal wheat.

Whitcomb, Day and Blish (*5*) reported that flour from sound wheat was found to be higher in baking value than flour from frosted wheat, the difference being small however, in cases where the frost damage was slight.

Whitcomb and Sharp (*6*) conducted an experiment in which the heads were harvested at various stages of growth and frozen artificially. They found that when the moisture content of the kernels was 46.5% or less at the time of freezing, the flour produced was superior to flour from normal wheat, and that when the moisture was higher than 46.5% at the time of freezing, the flour was inferior to flour from normal wheat.

Johnson and Whitcomb (*2*), after a study of frosted wheat produced both naturally and artificially, concluded that "wheat frosted when the moisture content is 44-46% or less appears to be equal in milling and baking quality to normal wheat, even though the percentage of wrinkled or blistered kernels may be relatively high."

Saunders, Nichols and Cowan (*4*) state in regard to forsted wheat: "It appears probable that sometimes, such wheat, provided it were plump, might yield good flour, but one could not advise any miller to use frozen wheat unless it had given satisfactory results in an experimental trial of its flour-making and bread-making qualities. In any case, one could not expect to

obtain good flour from frozen wheat weighing less than about 60 pound to the bushel, and even quite plump samples would have to be viewed witl suspicion." This probably represented the concensus of opinion regardin frozen wheat when the 1928 crop commenced appearing on the market.

A Study of the Commercial Grades, 4, 5 and 6.

In ascertaining the milling and baking characteristics of a crop it is com mon practice to use samples of the grade averages from the various inspectio points. However, while a study of the averages of the grades passing given inspection point may serve to give a general idea of the quality, it fail to reveal the degree of uniformity within the grades and this is a matter o some importance to both the overseas buyer and the domestic miller.

Of two lots of materials possessing equal average quality, the more de sirable is the one showing the lesser variation in its component parts. Aver age values are rather meaningless unless one knows the values from whicl they were calculated. In the hope of gaining some information regardin the range of variability as well as the average value of the quality of th commercial grades of the 1928-29 crop, a study of a number of typica examples of Grades 4, 5 and 6 was undertaken.

The material used in this investigation consisted of various samples o the commercial grades obtained from the Grain Standards Board. Thes were considered to represent the means and extremes of the three grades and were selected from samples used by the Grain Standards Board in com posing the standards for Grades 4, 5 and 6. One sample of feed wheat wa included in this series. The analytical data, flour yields, and physical ex amination data of these samples are given in table 1.

The physical examinations must be considered as quite approximate The number of classes separated was kept as small as possible in order t avoid confusion in the meaning of terms. The results given represent th mean of determinations made independently by two persons. Kernels show ing bran wrinkling to the crease were classed as heavily frosted. Under th heading "heavily frosted" two divisions were made, namely, "mature" an "immature and green." By "heavily-frosted mature" kernels are meant thos kernels which are plump and nearly normal in color. The term is used t distinguish these from the plump green and bronze kernels which occu very frequently. Under the heading "immature and green" are classed ker nels of all degrees of immaturity from bronze to shrivelled green.

It will be seen from an examination of table 1 that the damage in thes samples is not due to frost only. Samples 183, 185, 186, 187 and 197 sho little or no damage from this cause. The particular reason for these bein low in grade is the presence of a high percentage of immature and gree wheat. Excepting frost, this was the greatest source of damage to the grad of wheat of the 1928 crop.

Attention should be directed furthermore to the data for crude protei content of wheat. Several of the samples, notably Nos. 183, 189 and 19 were very low in protein. In a comparison of the effects of a particula type of damage, this fact would introduce a variable which would tend t obscure the results obtained. Such low values even in wheat grading No. Northern would in all probability result in poor baking value of the flou

TABLE 1. *Milling, analytical and physical examination data on wheat of the commercial grades—1928 crop.*

Laboratory No.	Grade	Protein of wheat (13.5% moisture basis) %	Milling Data: Straight flour %	Milling Data: Total flour %	Protein of flour (13.5% moisture basis) %	Ash of flour (13.5% moisture basis) %	Physical Examination: Unfrosted: Normal %	Physical Examination: Unfrosted: Immature and green %	Physical Examination: Unfrosted: Piebald and starchy %	Physical Examination: Bran-frosted %	Physical Examination: Heavily frosted: Mature %	Physical Examination: Heavily frosted: Immature and green %
183	No. 4	9.4	67.6	71.4	8.5	0.55	24	19	54	3		
184	" 4	12.8	70.0	74.1	12.2	0.42	45	10	3	8	34	
185	" 4	12.8	70.0	74.0	12.2	0.44	56	30		7	7	
186	" 4	13.2	69.6	72.7	12.4	0.48	23	73*	4			
187	" 4	14.6	70.4	74.1	14.4	0.52	51	43*	2	4		
188	" 4	13.6	67.8	72.1	13.1	0.57	28	10†	4	11	38	9
189	No. 5	9.9	67.3	71.0	9.0	0.62		14	11‡	8	40	27
190	" 5	11.5	67.3	72.0	10.7	0.56	2	3	4	4	52	35
191	" 5	12.5	70.3	73.4	11.9	0.49	15	13	2	11	19	40
192	" 5	12.8	71.8	74.7	11.9	0.49	12		2	4	62	20
193	" 5	13.4	66.6	71.9	12.7	0.53	3	10		10	40	37
194	No. 6	13.5	65.7	71.7	13.1	0.61	6	10		3	56	25
195	" 6	11.6	56.9	65.0	10.4	0.53	1			6	50	43
196	" 6	13.3	65.1	71.6	12.4	0.46	4			8	68	18
197	" 6	12.9	66.4	72.3	12.0	0.51	15	57	1	12	7	8
198	" 6	13.6	58.3	65.0	12.1	0.63	4				43	53
199	Feed	10.6	56.1	65.3	9.2	0.62	4				25	71

* Green and badly shrivelled.
† Shrunken only.
‡ Starchy - frosted.

One might be justified therefore in discarding these samples in a study of frost damage, or damage due to the presence of green and immature wheat. Since, however, the purpose of this particular study is to obtain an estimate of the quality of the individual samples which may be expected to occur in the commercial grades in order to gain an approximate idea of the composition of the average of the grades, it has been thought advisable to make no omissions.

The average crude protein content of wheat of the three grades was, for grade 4—12.7%; for grade 5—12.0%; and for grade 6—13.0%.

The average total flour yield was, for grade 4—73.1%; for grade 5—72.6%; and for grade 6—69.1%. The flours obtained from the samples having a very high percentage of frosted wheat, namely, Nos. 189, 195, 198 and 199, were quite dark in color.

The data for protein content of flour and ash content of flour were obtained with a straight flour consisting of all flour milled except the feed flour. The values for total flour represent the sum of the straight and feed flours.

In addition to the straight flour, a 55% patent was extracted in a second milling of these samples. The two millings were performed in order to ascertain if there would be any marked difference in the order of value of the wheats in the series, when tested by use of flours of such widely different extractions. Particularly in the case of frost damage, it was considered desirable to know if the damage were external or fairly deep-seated. If it were external, the short patent might be expected to show superiority over a straight flour.

The baking procedure followed in this laboratory has been described in detail by Larmour and MacLeod (*3*). The procedure is strictly fixed, so that all flours are treated in exactly the same manner. The basic formula involves the use of flour, water, yeast, sugar, and salt, only. The bromate formula involves the use of the same amounts of these ingredients with the addition of 1 milligram of potassium bromate. Identical procedures are used in both cases.

The baking data by the basic formula, for both the 55% patent and straight flours, are given in table 2.

Comparing first the two flour extractions, it will be observed that the absorption of the straight flours was in all cases higher than the absorption of the baking scores of grades 4, 5 and 6 were for the 55% patent flour, 80 general slightly higher than for the straights. With regard to the computed baking score*, there were variations in both directions. The average values of the 55% patent. Both texture and crumb color of the patents were in 88 and 91 respectively, and for the straight flours, 79, 83, and 90 respectively.

A comparison of the behaviour of these two series of flours when baked by the bromate formula is given in table 3. The average values of the baking score by the bromate formula for grades 4, 5 and 6 were for the 55%

* Computed baking score is calculated as follows:
(Loaf volume cc. minus 400) × 0.2
Texture × 8
Crumb Color × 2
Appearance × 1
(Absorption % minus 60) × 1
Sum of values so obtained equals Computed Baking Score.

TABLE 2. *Comparison of baking data on 55% patent and straight flours experimentally milled from wheat of the commercial grades—1928 crop.*
I. Basic Formula.

Laboratory No.	Grade	55% Patent Flour: Absorption of flour %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score	Straight Flour: Absorption of flour %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
183	No. 4	61	530	6	6	8	65	62	510	5	6.5	9	61
184	" 4	61	565	6	7	8	74	63	557	6.5	8.5	9	80
185	" 4	63	550	6	7	8	73	65	532	5.5	8	9	73
186	" 4	64	564	6	7	7	76	66	542	5	6.5	8	70
187	" 4	63	519	6	7	8	77	65	569	6	7.5	9	81
188	" 4	63	728	7	8	8	114	64	708	6	8	10	110
189	No. 5	64	532	7	6	9	73	67	540	6	4	10	71RC
190	" 5	63	577	6.5	6	10	80	66	535	5	5	10	68
191	" 5	65	600	6	6	8	83	68	544	4.5	4.5	10	69
192	" 5	66	608	8	8	10	98	69	590	8	5.5	10	92
193	" 5	66	634	9	7	10	104	69	652	9.5	8	10	114
194	No. 6	68	640	8	7	10	104	69	670	8.5	8	10	114
195	" 6	69	542	5	4	10	70RC*	71	519	4	4	10	65RC
196	" 6	67	649	7	8	10	104	71	645	7.5	7.5	10	108
197	" 6	68	627	5.5	7.5	8	93	72	607	3	7	10	86
198	" 6	69	621	4.5	5	10	85	74	597	3	3.5	10	79RC
199	Feed	72	494	4	3.5	9	59RC	75	492	2	2	6	49RCT†

55% Patent Flour	Straight Flour
Average Computed Baking Score Grade 4=80	Average Computed Baking Score Grade 4=79
" " " " " 5=88	" " " " " 5=83
" " " " " 6=91	" " " " " 6=90

* RC means "Rejected on account of color".
† RCT means "Rejected on account of both color and texture."

TABLE 3. *Comparison of baking data on 55% patent and straight flours experimentally milled from wheat of the commercial grades—1928 crop.*

II. Bromate Formula.

Laboratory No.	Grade of flour	55% Patent Flour						Straight Flour					
		Absorption %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score	Absorption of flour %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
183	No. 4	61	545	7	8	8	75	62	520	7	7	8	69
184	" 4	61	716	5	9	9	116	63	713	10	10	10	126
185	" 4	63	685	10	10	9	119	65	695	9	10	10	121
186	" 4	64	720	9	10	9	124	66	712	10	10	10	128
187	" 4	63	724	9	10	9	124	65	734	10	10	10	132
188	" 4	63	775	6	10	10	126	64	825	10	10	10	149
189	No. 5	64	520	7	5.5	10	70	67	479	5.5	4	10	57RC*
190	" 5	63	592	7.5	7	10	88	66	577	8.5	5	10	87
191	" 5	65	679	7.5	10	10	113	68	723	9.5	9	10	129
192	" 5	66	678	7.5	10	10	114	69	640	9	6	10	106
193	" 5	66	722	9	10	10	127	69	755	9.5	7.5	10	134
194	No. 6	68	720	10	10	10	132	69	754	10	9.5	10	139
195	" 6	69	512	4.5	5	10	65	71	496	5	4	10	63RC
196	" 6	67	713	7	9.5	10	120	71	752	9	8.5	10	135
197	" 6	68	660	8	10	10	114	72	662	8	9	10	116
198	" 6	69	572	4	4	10	73RC	74	576	4	2	10	75RC
199	Feed	72	433	3	3	3	37RC	75	432	2	2	6	37RCT†

55% Patent Flour	Straight Flour
Average Computed Baking Score Grade 4=114	Average Computed Baking Score Grade 4=121
" " " " " 5=103	" " " " " 5=103
" " " " " 6=101	" " " " " 6=106

* RC means "Rejected on account of color".
† RCT means "Rejected on account of both color and texture."

patent flour, 114, 103 and 101 respectively, and for the straight flours 121, 103 and 106 respectively.

The differences shown by the two series of flours were small, and since the results in either case lead to the same conclusions, the following discussion will be confined to the straight flours.

Turning now to a consideration of the quality of wheat of the different grades, as expressed by the baking results with the basic formula, it seems that on the average the No. 6 wheats are slightly superior to the No. 5 wheats, which are in turn distinctly superior to the No. 4 wheats. Larmour and MacLeod (*3*) have indicated, however, that the basic baking procedure when used with experimentally milled hard wheat flours is not wholly to be relied upon to give a true measure of the quality of the wheat. Many erroneous ideas have originated from placing too much faith in the results of a single baking method.

When one turns to the results given by the bromate formula, as shown in table 3, a different conclusion is reached. By this method, the average scores were 121, 103 and 106 for the No. 4, No. 5 and No. 6 wheats respectively. If the results obtained with the bromate differential test are at all indicative of the potential value of the wheat, it is apparent that Grade 4 wheats are on the average considerably superior in quality to the samples of the two lower grades. Nevertheless the average scores of 103 and 106 connote excellent baking quality.

Examination of the individuals of the various grades shows that of the No. 4 wheats, one was quite poor. This sample, No. 183, was exceedingly starchy and had a value for crude protein of wheat of only 9.3%. Poor quality due to starchiness is quite different from poor quality due to damage. Of the No. 5 wheats, one, namely No. 189, showed unmistakable signs of weakness due to damage. It decreased 20% in baking score with the bromate formula, and gave bread of very poor color.

In the No. 6 group, two samples, namely Nos. 195 and 198, gave negative responses to the bromate, and both were very poor in color. According to our color scale, 4 denotes dark grey, and any flour scoring 4 or lower for color is considered "rejected" from the point of view of use in milling domestic flours. These three flours failed to improve in either volume or crumb color when baked with bromate, and must be considered undesirable for milling alone or for blending. Summing up, there was found in the No. 4 group, one sample showing great weakness in regard to loaf volume but otherwise acceptable; in the No. 5 group, one sample had to be rejected on account of color and was otherwise very poor; in the No. 6 group, two of the five samples were exceedingly weak and wholly undesirable for production of domestic flour. From the foregoing consideration of these data, it appears that the variation in Grade No. 6 is greater and more serious than in Grade No. 5, and the variation in the latter is greater than in Grade No. 4.

In the case of the No. 6 flours, one might predict that the high value of the three good ones would entirely mask the low values of the two bad ones, if equal quantities of these flours were blended. In order to test this surmise, blends consisting of equal portions of each flour were made for the three

grades, using 55% patent flour. The results are shown in table 4. The values for the composites were in general somewhat higher than the averages of the individuals, but the order was unchanged.

The bromate differential test as used gives a fairly good estimate of the value of flour, and enables one to predict with some accuracy the probable potential strength of wheat or flour from the standpoint of its value in blending. The group representing Grade 6 for instance, gives a good average score, and when the flours are mixed, the score is even better. Obviously, however, a mixture consisting of three parts good flour and two parts poor flour has not as much reserve strength as one consisting of four parts good and one part poor flour, provided, of course, that the poor flours are of approximately equal strength. Part of the strength of the flour representing the strong portion of the mixture must be used in bolstering up the strength of the low quality portion, so that the value of the mixture for further blending purposes must be decreased.

TABLE 4. *Baking data on grade composites.*
55% Patent Flour— I. Basic Formulla.
II. Bromate Formula.

Grade	Baking Formula	Absorption of flour %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
Composite No. 4	I	64	566	6	8	9	80
	II	64	719	9.5	10	10	126
Composite No. 5	I	66	584	8.5	7	9	91
	II	66	666	9.5	9	10	116
Composite No. 6	I	68	626	7	6	9	95
	II	68	670	7	7	10	107

In order to obtain an estimate of the blending value of these various flours, it was decided to mix them with an exceedingly weak flour and bake them. For this purpose a flour milled from Pacific White Club wheat with a crude protein content of 7.5% was chosen. The formula used in these bakings was:

Soft wheat flour	40	Grams	13.5% moisture basis.
Flour being tested	60	"	
Sugar	2.5	"	
Yeast	3	"	
Salt	1	"	
$KBrO_3$	0.001	"	
Water	as required		

In choosing a blend suitable for experimental baking tests it seemed advisable to select a flour of pronounced weakness and then add to the strong flour an amount sufficient to cause a material reduction of baking value in the mixture. The proportion of soft wheat flour therefore should slightly exceed the optimum capacity of a normal strong flour. If in a given series of flours, the treatment accorded to each is identical, differences in blending capacity should be reflected in the degree of degradation of baking value effected as a result of the addition of weak flour. In order to study differences, one must be sure that differences will be produced if they exist. Re-

TABLE 5. *Baking data on experimentally milled flours from wheat of the commercial grades—1928 crop.*

Straight Flour—III. Blend Formula—40% White Club Wheat Flour, 60% Experimentally Milled Flour plus 0.001% $KBrO_3$

Laboratory No.	Grade	Absorption of flour %	Loaf volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
183	No. 4	60	499	6	6	7.5	57
184	" 4	61	599	9.5	9	9	96
185	" 4	62	605	10	9	8.5	99
186	" 4	62	635	9.5	8.5	9.5	104
187	" 4	63	630	9.5	9.5	9.5	106
188	" 4	62	681	7.5	8.5	9.5	107
189	No. 5	64	470	3	4	10	45 RC*
190	" 5	64	518	7	6	9.5	70
191	" 5	65	580	10	7.5	10	96
192	" 5	66	543	7	5.5	10	77
193	" 5	66	556	8.5	7	10	87
194	No. 6	64	541	8.5	6.5	8.5	79
195	" 6	64	430	6.5	4.	5.5	43 RC
196	" 6	66	542	8.5	6.5	10	83
197	" 6	66	539	7.5	6	9	77
198	" 6	66	488	2.5	3	6	43 RCT†
199	Feed	67	393	3.5	0.5	4	21 RC
White club wheat flour		51	346	3	1.5	0	–7
Composite No. 4		62	595	10	9	10	99
Composite No. 5		62	495	9	6	8	68

Average Computed Baking Score—Grade 4=95
" " " " " 5=75
" " " " " 6=65

* RC means "Rejected on account of color".
† RCT means "Rejected on account of both color and texture."

sults of preliminary tests showed that 40% of Club wheat flour was sufficient to reduce the baking score of a normal high grade spring wheat flour to about 15% below the original value obtained by the bromate formula.

The $KBrO_3$ was used because it affects the soft wheat flour to no appreciable extent, and it was thought desirable to give the hard wheat flour every opportunity to show its strength. The baking data are given in table 5.

The results of this test leave little doubt regarding the relative merits of these wheats in regard to blending value. No. 183, being very low in protein, fell down badly in the blend, but the other five samples of grade 4 stood up very well indeed, the average for the grade being 96 for computed baking score. Of the samples of grade 5, only one showed a baking score of over 90, three being 80 or lower. Of the samples of grade 6, only one gave a baking score of over 80, and two of them were close to 40. The feed wheat sample showed a score of only 21.

The average values for each grade are shown at the bottom of table 5. Baking scores calculated as percentages of the average for grade 4 give 77% for the average of grade 5, and 66% for the average of grade 6. A composite sample made up of equal quantities of each sample in the particular grades was prepared of grades 4 and 5, and these were baked in a blend as the others. The values obtained were 99 and 68 respectively. The score for the grade 4 composite was slightly higher, and for the grade 5 composite considerably lower, than the average score of those respective grades.

There can be no doubt that on the average the No. 6 wheats are very inferior to the No. 5 wheats, and that these latter are very inferior to the No. 4 wheats in strength. It should be noticed however that in grade 4 a sample of flour giving by this method a score of 56 (very poor) was found in company with five samples of high blending capacity. As mentioned before, No. 183 could be mixed readily with the other samples of this grade without any serious injury to the color resulting, because it is weak due to starchiness only, but it is certain that an admixture of such a wheat would reduce the blending value of the mixed sample.

The results obtained with these flours by the method of blending present a very different conception of the wheats than was obtained from the use of the basic formula. By the basic method, the flours from No. 6 wheat were shown to be, on the average, superior to those from No. 5 wheat, and these in turn were superior to those from No. 4 wheat. The bromate formula changed this order, making the No. 4 better on the average than either the No. 5 or No. 6. But this test showed high baking scores for the No. 6. By use of the blend with White Club wheat, very marked differences between the grades and between samples in the individual grades were revealed. The conclusion reached as a result of this work is that heavy frost damage irrespective of protein content materially decreases the strength of wheat from the standpoint of its usefulness for blending purposes.

The foregoing discussion has been confined to the commercial grades only. A comparison of the data obtained by the three baking methods, with data similarly obtained for high grade wheat, is desirable. A series of 38 samples of pure Marquis wheat of exceptionally high grade, grown in 1928 in various parts of Saskatchewan, was tested in this laboratory. In this series, 16 samples graded 1 hard, 19 graded 1 Northern and 3 graded 2 Northern. The average crude protein content of wheat for the series was 13.3%. It is considered that the average values for such a collection of samples would represent nearly the maximum average for the 1928 crop, and it seems justifiable to use these values as a standard for comparison.

The average baking scores by the basic, bromate and blend formulae were 88, 118 and 96 respectively. The baking scores of the straight flours, Nos. 183-199 inclusive, were calculated as percentages of the value for the standard described above. The results are given in table 6.

This presentation of the data does not alter in any respect the conclusions previously reached regarding the relative value of grades 4, 5 and 6. It is interesting to note however, that by the basic formula, the average for the samples of grade 6 in addition to being higher than the average for the samples of grade 5 and grade 4 is slightly higher than even the average for the 1 Northern samples. The inferiority of wheat of grades 5 and 6 is shown by the calculation for the bromate and blend formulae. There should not be overlooked, however, the fact that in each of the commercial grades, certain individuals were found by all the tests employed to possess medium to high quality when compared to the standard values used.

The conclusions which are drawn from the foregoing data may be briefly summarized as follows:

1. Flours from wheat of grades 5 and 6 show generally a pronounced gray color which is exceedingly objectionable, and which makes these wheats very undesirable for use in blending with sound wheats for the manufacture of high grade flours.

2. Considered from the standpoint of use in blending, as determined by our blend formula baking procedure, the wheat of grade 6 was on the average lower in value than the wheat of grade 5, and this was very considerably lower than the wheat of grade 4. The results obtained by the bromate differential procedure gave a fairly good indication of the behaviour of the flour in the blend. Since the data obtained by the basic formula (I) alone fail to agree with either the bromate (II) or the blend (III) procedures, it is thought that the former is liable to give erroneous results in many instances, and is not to be solely relied upon in testing quality of wheats.

3. While the samples of grade 4 were found to be on the average equal in strength to wheat of the higher grades, there is liable to be found a remarkable lack of uniformity in this grade. In the samples tested, this was due to the occurrence of one sample of starchy wheat which was very low in strength. In mixed samples of No. 4 wheat, the presence of such starchy wheat would tend to be masked, but the fact that they are included has the effect of lowering the blending value of wheat of this grade. The variation in strength seems to be still more pronounced in grades 5 and 6.

TABLE 6. *Computed baking scores of Tables 3, 4, 5 and 6 calculated as percentages of the standard average score.*

Laboratory No.	Grade	I. Basic Formula		II. Bromate Formula		III. Blend Formula	
		Computed Baking Score	Percentage	Computed Baking Score	Percentage	Computed Baking Score	Percentage
Standard		88	100	118	100	96	100
183	No. 4	61	69	69	58	57	59
184	" 4	80	91	126	107	96	100
185	" 4	73	83	121	102	99	103
186	" 4	70	80	128	108	104	108
187	" 4	81	92	132	112	106	110
188	" 4	110	125	149	126	107	111
Average			90		102		98
189	No. 5	71	81	57	48	45	47
190	" 5	68	77	87	74	70	73
191	" 5	69	78	129	109	96	100
192	" 5	92	104	106	90	77	80
193	" 5	114	130	134	114	87	91
Average			94		87		78
194	No. 6	114	130	139	118	79	82
195	" 6	65	74	63	53	43	45
196	" 6	108	123	135	114	83	86
197	" 6	86	98	116	98	77	80
198	" 6	79	90	75	64	43	45
Average			103		89		68
199	Feed	49	56	37	31	21	22
55% patent flour							
Composite No. 4		80	91	126	107		
Composite No. 5		91	103	116	98		
Composite No. 6		95	108	107	91		

COMPARISON OF FROSTED AND UNFROSTED WHEAT FROM A SMALL LOCALITY

Working with wheat of unknown history is always more or less unsatisfactory. This is particularly true in studying the effect of damage of vari-

Table 7. *Milling, analytical and physical examination data on samples of wheat of the 1928 crop grown within a small district.*

Laboratory No.	Grade	Milling Data					Physical Examination					
		Protein of wheat (13.5% moisture basis)	Straight flour	Total flour	Protein of flour (13.5% moisture basis)	Ash of flour (13.5% moisture basis)	Unfrosted			Bran-frosted	Heavily frosted	
							Normal	Immature and green	Piebald and starchy		Mature	Immature and green
		%	%	%	%	%	%	%	%	%	%	%
585	2 Nor.	12.35	69.6	74.4	12.0	0.46	85	10	4	1		
587	2 Nor.	13.3	69.0	73.0	13.0	0.45	83	13	2	2		
589	No. 4	12.25	71.4	74.2	12.2	0.44	60	33*	3	4		
597	No. 5	13.5	68.4	72.5	12.9	0.43	26			18	38	18
596	" 5	11.7	65.7	70.4	11.3	0.51	57	16	5	15	7	
595	No. 6	12.1	63.8	70.4	11.6	0.47	14	10	3		26	47
590	" 6	12.56	60.4	67.1	12.0	0.49	12		1	3	34	50
598	" 6	12.55	61.9	68.5	11.9	0.57	26†			12		62
586	" 6	12.34	57.0	66.6	11.9	0.71	3		2	16	33	46
588	" 6	11.7	61.2	67.0	11.1	0.55	3				19	78

* Very slightly green.
† Badly bleached.

ous sorts, because there is no means for ascertaining what the character of the wheat might have been had it matured normally under the same conditions of soil and climate. Sound wheat grown in different localities frequently shows wide differences in quality. It is highly desirable therefore, in testing damaged wheat, to know as accurately as possible the normal value of wheat grown under the same conditions.

With these considerations in mind, a number of samples of frosted and unfrosted wheat were obtained from a particular district. Nine samples were secured from within an area of 3 x 8 miles and a tenth from 7 miles south of that. Analytic data, flour yields and descriptions of these samples are given in table 7.

Three of the ten samples contained only a trace of bran-frosted wheat. Two of these, grading 2 Northern, had over 80% of normal wheat, while the third, grading 4, had 60% normal and 33% slightly green wheat. The five No. 6 samples all showed high percentages of heavily frosted wheat. Of the two No. 5 samples, one contained 74% frosted wheat, and the other only 22% frosted wheat.

In respect to crude protein of wheat, the variation was not exceptionally great, the range being 11.7% to 13.5%. Such differences in protein content, tend to obscure the results of the baking tests, but it seems impossible to avoid with samples collected as these were.

TABLE 8. *Baking data on samples of wheat of the 1928 crop grown within a small district.*

Straight Flours— I. Basic Formula.
II. Bromate Formula.
III. Blend Rormula.

Laboratory No.	Grade	Baking Formula	Absorption %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
585	2 Nor.	I	59	525	7	8	7	68
		II	59	613	10	10	10	102
		III	58	590	10	8	9	91
587	2 Nor.	I	62	585	4	7	8.5	73
		II	62	730	9.5	10	10	127
		III	58	640	10	7	10	100
589	No. 4	I	62	565	7	8	8.5	80
		II	62	667	10	10	10	115
		III	58	610	9.5	8	10	94
597	No. 5	I	65	626	5	5.5	8.5	85
		II	65	731	7	9	10	120
		III	61	567	7.5	5.5	9.5	77
596	No. 5	I	64	606	4.5	6.5	9	81
		II	64	622	7	8	10	95
		III	60	579	6	6.5	9	76
595	No. 6	I	64	610	3.5	4	9	73 RC
		II	64	622	6	6	10	88
		III	61	581	6	6	9.5	77
590	No. 6	I	68	600	4	3	9	75 RC
		II	68	630	7	4.5	10	94 RC
		III	62	533	4	4	8.5	57 RC
598	No. 6	I	66	569	4	3	9.5	67 RC
		II	66	556	2.5	4	10	63 RCT
		III	63	552	1.5	2.5	7	50 RCT
586	No. 6	I	66	545	4	3	9	62 RC
		II	66	540	2.5	3.5	10	58 RCT
		III	62	495	3	2.5	8	43 RC
588	No. 6	I	68	585	4.5	3.5	9.5	75 RC
		II	68	553	3.5	4	10	67 RC
		III	62	471	4.5	2.5	5.5	40 RC

The baking data obtained by use of the basic, bromate and blend formulae are given in table 8. In all cases the No. 6 flours showed marked inferiority in color. The baking results by the basic formula indicate that in respect to baking quality, the lower grade wheats with the exception of Nos. 586 and 598 were equal to or better than the high grade wheats. This is in agreement with the results given in table 2 for the Grain Standards Board samples.

As in the former case, the order of values changed when the bromate formula was used. Nos. 586, 588 and 598 showed actual decreases in baking score, while Nos. 585, 587 and 589 showed very marked increases. The other four samples of the group showed a fair positive response to the bromate. The results by this baking indicate that three of the five samples grading No. 6, namely Nos. 586, 588 and 598, were of very low strength. Both samples grading 2 Northern and the sample grading 4 showed very excellent quality. Two No. 6 samples, namely Nos. 590 and 595, showed a good degree of quality.

The blend formula accentuated the weakness of those flours found to be weak by the bromate formula, and exposes in some cases weakness not before suspected. Such a case is No. 597.

In order to facilitate comparison of the results obtained by the use of the three different formulae, the baking scores have been calculated as percentages of the mean of the values of Nos. 585 and 587. For each set of baking re-

TABLE 9. *Computed baking scores of Table 8. Calculated as percentages of the average score of the 2 Northern samples*

Laboratory No.	Grade	I. Basic Formula		II. Bromate Formula		III. Blend Formula	
		Computed Baking Score	Percentage	Computed Baking Score	Percentage	Computed Baking Score	Percentage
Average of 585 & 587	2 Nor.	70	100	115	100	96	100
589	No. 4	80	114	115	100	94	98
597	No. 5	85	121	120	104	77	80
596	" 5	81	116	95	83	76	79
595	No. 6	73	104	88	76	77	80
590	" 6	75	107	94	82	57	59
598	" 6	67	96	63	55	50	52
586	" 6	62	89	58	50	43	45
588	" 6	75	107	67	58	40	42

sults, this score was taken as 100 and the others calculated to this basis. The calculations are shown in table 9. These figures tend to lend emphasis to the foregoing observations regarding the results obtained by the three bakings. It seems evident that the basic formula cannot be relied upon as the sole test of baking quality of flours. The results of the tests on this series of samples may be summarized briefly as follows:—

1. The wheats of grades 2 Northern and 4 were found to be high in milling and baking quality, and no significant difference between them was found.

2. In milling quality one sample of No. 5 was nearly equal to the 2 Northern but the other No. 5 and all the No. 6 samples were found to be decidedly inferior in this respect.

3. Four of the five samples of No. 6 were found to be exceedingly poor, especially in blending quality.

4. The two samples of No. 5 and one No. 6, namely No. 595, were of medium quality and approximately equal in blending value.

These results, although obtained with a small number of samples, are probably fairly indicative of the relative value of the different grades of wheat produced in the limited district from which they were obtained. The principal objection to the use of data such as these for generalization is the fact that the quality that the wheat might have attained had it come to normal maturity, is not definitely known, and therefore comparisons must be based on a more or less hypothetical value for the sound wheat.

Comparison of Frosted and Unfrosted Wheat From the Same Field

At the time of the occurrence of the first frost in August, 1928, harvesting had commenced in many parts of the province. We were able, therefore, to obtain a number of wheat samples in pairs representing grain from the same field, cut before and after the frost. In addition to these, three pairs of samples, representing wheat at different stages of maturity when the frost occurred, were obtained from the University Farm at Saskatoon.

These samples were considered to be much more suitable for the study of effect of frost than the material used in the previously described studies, for the reason that in each case there was an unfrosted sample for use as a standard for comparison. The principal error would be due to differences which exist in the same field.

The analytic data, flour yields and physical examination data are given in table 10. Through an oversight, no samples of Nos. 26 and 27 were retained, and the physical examination was not made on them. There are fairly wide differences in protein content of wheat for members of a pair in several cases. Nos. 141 and 140 show the greatest variation in this respect. Nos. 27 and 26 show a difference of 0.9% and Nos. 69 and 71 show a difference of 0.7%. The samples of the latter pair, both grown on a 1/10th acre plot at Saskatoon, show what variation in crude protein may be expected to occur within very short distances.

The yield of straight flour from the frosted wheat was lower in all cases than the yield of the corresponding sound sample. Ash of the flour from the frosted wheat was higher in all cases than the ash of the flour from the corresponding sound samples.

The detailed baking data by the three formulae are given in table 11.

It should be noted that in practically all cases, the texture and crumb color scores of the frosted samples were lower than for the corresponding sound samples. In five of the eight pairs, the crumb color of bread baked from the frosted wheat flour was so low that they could be classed as rejected on that account. The baking scores of the frosted samples were calculated as percentages of the corresponding unfrosted samples and these values are shown in table 12. As in the studies previously discussed, the results by the basic formula give an erroneous impression. Three of the samples grading No. 5 showed better scores than their corresponding sound samples which graded 2 Northern, while No. 118 grading No. 5 was virtually as high in score as No. 119 which graded No. 1 Northern.

TABLE 10. *Milling, analytical and physical examination data on frosted and unfrosted samples of wheat from the same field—1928 crop.*

Laboratory No.	Grade	Protein of wheat (13.5% moisture basis) %	Milling Data		Protein of flour (13.5% moisture basis) %	Ash of flour (13.5% moisture basis)	Physical Examination					
			Straight flour %	Total flour %			Unfrosted			Bran-frosted	Heavily frosted	
							Normal	Immature and green	Piebald and starchy		Mature	Immature and green
119	1 Nor.	13.80	71.0	75.2	13.20	0.40	81	15	2	2		
118	No. 5	13.50	69.3	75.5	13.00	0.45	35	29	4	8	24	
141	2 Nor.	11.50	70.5	75.5	10.60	0.46	69	29	1	1		
140	No. 5	13.20	64.1	72.6	11.90	0.49	9			30	21	40
143	2 Nor.	13.10	70.7	75.3	12.00	0.40	65	24	6	3	2	
142	No. 5	13.30	66.7	73.0	12.40	0.47	28	10	6	13	43	
210	3 Nor.	12.10	69.4	74.9	11.80	0.49	76	22	2			
207	No. 6	11.70	68.7	75.1	11.50	0.55	25	4	3		10	58
27	No. 4	13.50	62.5	73.8	12.10	0.44						
26	Feed	12.60	49.1	62.4	12.10	0.47						
69	2 Nor.	10.50	69.3	73.5	10.00	0.56	46	9	41	4		
71	No. 4	9.80	66.8	72.8	9.00	0.58	6	3	8	12	38.33*	
96	2 Nor.	14.10	72.0	76.0	13.70	0.44	71	23	3	3		
94	No. 6	14.40	56.9	64.1	13.20	0.59	4		1	4	18	73
96	2 Nor.	14.10	72.0	76.0	13.70	0.44	71	23	3	3		
95	No. 5	13.90	69.1	73.2	13.50	0.46	36	11		29	24	

* Starchy - frosted.

TABLE 11. *Baking data on frosted and unfrosted samples of wheat from the same field—1928 crop.*
Straight Flours— I. Basic Formula.
II. Bromate Formula.
III. Blend Formula.

Laboratory No.	Variety	Grade	Baking Formula	Absorption %	Loaf Volume cc.	Texture	Crumb Color	Appearance	Computed Baking Score
119	Marquis	1 Nor.	I	61	566	9	10	9	90
			II	61	710	9	10	10	120
			III	59	605	10	9	7.5	96
118	Marquis	No. 5	I	61	599	6.5	9	9	87
			II	61	713	9	10	10	121
			III	60	549	9.5	7	7	79
141	Garnet	2 Nor.	I	61	529	6.5	6	9	67
			II	61	550	8	6	8	75
			III	60	517	6.5	7	5.5	62
140	Garnet	No. 5	I	63	558	6	4	10	71 RC
			II	63	530	4	4	7	56 RC
			III	60	436	4	4	5	32 RC
143	Garnet	2 Nor.	I	62	528	6.5	7.5	8	70
			II	62	691	9	10	9	116
			III	60	608	9.5	8	7	93
142	Garnet	No. 5	I	62	592	6.5	6.5	9	82
			II	62	679	8	8	9	107
			III	62	585	8.5	7	7	83
210	Marquis	3 Nor.	I	61	559	2	5	6	55 RC
			II	61	661	8.5	8	10	105
			III	60	585	8	6	10	83
207	Marquis	No. 6	I	61	457	2.5	4	6	34 RCT
			II	61	576	5.5	4	10	71 RC
			III	60	528	5	3.5	8	56 RC
27	Marquis	No. 4	I	63	570	4	6	8.5	70
			II	63	643	9.5	10	10	110
			III	58	558	9.5	7	9.5	82
26	Marquis	Feed	I	62	500	4	4	9	51 RC
			II	62	500	4	4	9	51 RC
			III	60	448	2.5	2	4	25 RCT
69	Marquis	2 Nor.	I	64	480	4	5	8.5	51
			II	64	512	8.5	7.5	10	77
			III	58	488	6.5	5.5	9	56
71	Marquis	No. 4	I	64	453	3.5	5	8	43
			II	64	413	2.5	4.5	7	30 RCT
			III	58	380	2	4	2.5	10 RCT
96	Marquis	2 Nor.	I	64	605	7.5	7.5	10	92
			II	64	753	9.5	10	10	133
			III	58	595	10	7	9	90
94	Marquis	No. 6	I	64	498	2	3	6.5	42 RCT
			II	64	440	2	2.5	6	29 RCT
			III	58	404	2	3	2	13 RCT
96	Marquis	2 Nor.	I	64	605	7.5	7.5	10	92
			II	64	753	9.5	10	10	133
			III	58	595	10	7	9	90
95	Marquis	No. 5	I	64	627	9	7.5	10	101
			II	64	702	9.5	9	10	121
			III	58	555	10	7	9	82

TABLE 12. *Computed baking scores of Table 11—frosted calculated as percentage of unfrosted*

Laboratory No.	Grade	I. Basic Formula		II. Bromate Formula		III. Blend Formula	
		Computed Baking Score	Percentage	Computed Baking Score	Percentage	Computed Baking Score	Percentage
119	1 Nor.	90		120		96	
118	No. 5	87	97	121	101	79	82
141	2 Nor.	67		75		62	
140	No. 5	71	106	56	75	32	52
143	2 Nor.	70		116		93	
142	No. 5	82	117	107	92	83	89
210	3 Nor.	55		105		83	
207	No. 6	34	62	71	68	56	67
27	No. 4	70		110		82	
26	Feed	51	73	51	46	25	30
69	2 Nor.	51		77		56	
71	No. 4	43	84	30	39	10	18
96	2 Nor.	92		133		90	
94	No. 6	42	46	29	22	13	14
96	2 Nor.	92		133		90	
95	No. 5	101	110	121	91	82	91

By the bromate formula, the frosted equalled the unfrosted in only one case, namely Nos. 118 and 119. No. 142 scored 92% of its check, and No. 95 scored 91% of its check. In some of the other pairs, the difference was very large.

By the blend formula, all of the frosted samples showed inferiority to their unfrosted check samples. Nos. 118, 142 and 95 gave scores which were respectively 82, 89 and 91 per cent of their checks. These were the best of the frosted samples. The next in order was No. 207, which gave a score equal to only 67% of its check sample. The other four, namely Nos. 140, 26, 71 and 94 gave very low relative scores, and could scarcely be considered even fair milling wheats.

The pair consisting of Nos. 69 and 71 should probably have been excluded from this study, for although they were both grown on the same 1/10th acre plot, the fact remains that there was a wide difference in protein content of the flours, and the protein was exceedingly low. A difference representing 10% of the protein present is probably more significant in the lower range than in the higher. One would expect a large difference between flours of 10% and 9% crude protein. Therefore with this pair of samples, the difference shown can scarcely be attributed wholly to frost damage.

Summary and Conclusions

Some of the milling and baking characteristics of the lower grades of the 1928 crop of Western Canada were studied, using three different series of samples, namely:

(*a*) Representative samples of the commercial grades 4, 5 and 6, selected from the samples used by the Grain Standards Board in making up the standards for the commercial grades for 1928.

(*b*) Frosted and unfrosted samples grown in a very small typical locality of Saskatchewan.

(*c*) A number of pairs representing frosted and unfrosted wheat grown in the same field.

The flour from these samples was baked by three methods, in which the procedure was the same in each case and only the formula varied.

The basic formula used gives erroneous values with experimentally milled flours, inasmuch as perfectly sound high grade wheat flour frequently fails to show its true value by this method. Since, however, the formulae in common use are of this type, baking results by this method have been included to show the sort of results to be expected where this method alone is used. The results obtained by the basic method, considered in conjunction with the results by the bromate method, are useful in revealing the direction and magnitude of response attributable to the action of 0.001% $KBrO_3$ which is included in the latter formula. This response is indicative of the quality of the flour under consideration.

A blend consisting of 40% White Club wheat flour and 60% of the flour being tested, serves to give a measure of the reserve strength or blending capacity of the flours.

The conclusions drawn from the data obtained in these studies may be summarized as follows:

(1) Samples of grades 5 and 6 give on the average lower flour yields with higher ash and darker color than the higher grades of wheat.

(2) By the baking procedure commonly used, wheat of the lower grades, i.e., 4, 5 and 6, give values equal to or superior to wheat of the high grades.

(3) Study of the capacity of the flour to "stand up" in a blend with very weak flour, taken as a measure of strength of wheat, leads to the following conclusions:

- (i) Feed wheat is of little value.
- (ii) Wheat of grade 6 is on the average very poor.
- (iii) Wheat of grade 5 is very much superior to that of grade 6, but inferior to that of grade 4 on the average.
- (iv) Wheat of grade 4 is, on the average, comparable in strength to that of the higher grades.

(4) Study of the response of flours to the bromate formula gives fairly reliable data for predicting the behaviour of the flour when baked in a blend. Results by the basic formula seem to bear no relation whatsoever to the behaviour of the flour by the bromate formula or the blend formula, and for this reason it is considered that the basic formula alone is unreliable as a method for determining strength or quality of wheat.

(5) There is great variability of quality in grades 4, 5 and 6. In grade 4, the widest variation observed seemed to be due to starchy and piebald samples rather than to frost damage. Variability of quality is greater in grade 5 than in grade 4, and seems to be due to the occurrence of samples showing definite frost damage. In grade 6, there is a still greater incidence of severely damaged samples. In both these grades, however, even the best samples were found to be inferior to the average of grade 4, especially in regard to blending capacity.

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VARIATIONS IN THE SKELETAL STRUCTURE OF THE PIG*

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In his "Anatomy of Domestic Animals" published in 1917, in the portion dealing with the Anatomy of the Pig, Sisson states "The Vertebral formula is C7 T14-15 L6-7 Cy 20-23"; again, "The ribs number fourteen or fifteen pairs. The fifteenth rib when present may be fully developed and its cartilage enter into the formation of the costal arch; but in most cases it is only about an inch (2-3 cm.) in length"; again, "The occurrence of fifteen thoracic vertebrae is quite common and the existence of sixteen or even seventeen has been recorded. Reduction to thirteen is very rare. Six and seven lumbar vertebrae seem to occur with about equal frequency and reduction to five is on record."

When reading these statements it occurred to the writer that this variation might account for the very great difference in length so commonly found among pigs in general. The first step was to ascertain how many ribs the model pig skeletons used by Veterinary Colleges for teaching purposes possessed. The one in use by the Veterinary and Animal Husbandry Departments at the University of Saskatchewan was found to have 14 pairs of ribs. Since then several others have been seen and examined and in every case they possessed what apparently was considered to be the normal number, viz, 14 pairs.

Inquiry was made with regard to this question but neither veterinarians, breeders, butchers, bacon curers nor packing house operators could give any information concerning it. Even men who had been in the bacon-curing business all their lives and were actually cutting up hundreds of carcasses each week could not throw any light on the problem. In fact I did not succeed in finding anyone during the early stage of my investigation who could give a satisfactory answer to the question "How many ribs has a pig?"

In the year 1922, while watching the judging of a group of bacon hog carcasses at a western exhibition, I noticed that among the group (there were nine carcasses on the rail) there appeared two that were very much shorter than the others. After the awards had been placed I took advantage of the opportunity and counted the ribs in each carcass. I found that the first and second prize carcasses each had 16 pairs of fully developed ribs, the third, fourth and fifth prize carcasses each had 15 fully developed pairs of ribs and the sixth, seventh and eighth 14 pairs each. The ninth had 15 pairs.

Since then I have made rib counts at ten carcass competitions held at various western Canadian exhibitions and find that there appears to be a direct correlation between the number of ribs and the placing of the carcasses, providing of course that the quality and finish is equal in every case.

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At six of these competitions 16- 15- and 14-ribbed pigs appeared with the awards being made in the same order. At two competitions no 16-ribbed pigs were found, all of them possessing 15. At the two remaining competitions 16- and 15-ribbed specimens were found. The placing here differed from the preceding ones in that the first and third awards were won by 15-ribbed pigs while the second and fourth possessed 16. The explanation given by the judge, who was a bacon curer but who knew nothing about rib variation, was that the general finish of the first and third prize carcasses was very superior but that the second prize carcasses had a slight advantage in length of side but lacked somewhat in finish.

The judging at these competitions was done by experts who, as a rule, are thoroughly familiar with the requirements of the export trade. None of them examined the carcasses to ascertain the number of ribs present but made their placings entirely upon conformation, usually stressing length of side together with smoothness as well as quality and finish. As a matter of fact few if any of these judges were aware that a variation in number of ribs existed.

Since 1922, but more particularly during the past three years, some 3957 carcasses have been carefully examined at the University of Saskatchewan and at Canadian and United States abattoirs. Besides this first-hand information a considerable amount has been secured from England, Denmark and Germany.

Table 1 shows the actual variations found among 3957 animals representing several breeds, grades and crosses. Only the Canadian, American, British and Danish data are included in the table. There appears, from information that we have received, to be grounds for believing that the pigs of Germany show similar variations to those indicated in the table, but because of insufficient data of a definite kind we have not included them in our estimate.

Although the variation was supposed by Sisson to consist of an occasional "floater" or partially formed rib it will be seen from the above table that this is by no means the case. True, a number of the odd and imperfectly formed ribs of the floater type do appear but by no means as frequently as complete and perfect additional pairs. The groups where partial ribs appear, as in the columns headed 13+, 14+ and 15+, were all counted by members of our own department. The records made in Britain and elsewhere do not take into account anything except those animals showing perfect pairs of ribs. It would seem, however, that similar specimens of rudimentary or partially formed ribs must undoubtedly occur among British and European breeds.

The next question was whether a pig with 16 pairs of ribs actually had two more vertebrae than one with only 14 pairs. To decide this meant that a much closer study of the vertebral column had to be made. Our plan of attack was as follows: In the making of Wiltshire sides the back bones are removed from the carcass. This fortunate circumstance made it possible to secure plenty of material. Rib counts were made at the abattoir on the carcasses as they hung in the cooling rooms. To each carcass was

TABLE 1. *Showing numbers of ribs occurring in different breeds, grades and crosses.*

Breed	RIB NO.									
	13	13+*	14	14+	15	15+	16	16+	17	
Yorkshire			94	2	393	14	169	1	5	678
Berkshire	1		13		2					16
Tamworth			12		11					23
Duroc Jersey	1		175	24	246	13	25			460
Poland China	1	2	318	63	397	23	33			837
Chester White	4	6	314	70	231	10	6			641
Hampshire	1		121	11	120	9	13			275
Duroc Jersey† × Yorkshire			2	1						3
Yorkshire × Tamworth			1	1	5		2			10
Iowa grades	1		54		40		5			100
Large White			34		7		1			42
Middle White			40		21		2			63
Large Black			2		9					11
Wessex Saddlebacks			2		3					5
Gloucester Old Spots					12					12
Welsh			16		36		2			54
Lincolnshire Curly Coated			34		7					41
Large White × Large Black			5		10					15
Large White × Berkshire			21		8					29
Large White × Middle White			17		19		1			37
Oxford × Large White			17		13					30
Large White × Wessex Saddleback					1					1
Devon Lop Ear × Middle White					1					1
Large Black × Berkshire			1							1
Tamworth × Berkshire			35		13					48
Large White × Welsh			7		6					13
Large White × Essex			5		1					6
Welsh × Large White			22		37		10			69
Tamworth × Gloucester Old Spots			8		4					12
Tamworth × Yorkshire			6		10		3			19
Berkshire × Tamworth			5		6					11
Berkshire × Yorkshire			4		7					11
Yorkshire × Berkshire					2		1			3
Tamworth × Duroc Jersey			4		2					6
Yorkshire × Landrace	11		185		139		37		2	374
										3,957

*In 2nd, 4th, 6th and 8th columns are listed pigs showing uneven pairs or where one or more ribs were "floaters" or in any way defective.
†In the case of crossbred pigs (×) the breed of the boar is stated first

affixed a tag upon which was marked the number of ribs. When the backbone was removed from the carcass the tag was affixed to the backbone. In addition, postmortems were held on all young pigs that were lost at farrowing time in the University herds. These data have been gradually collected over a period of years. In a number of cases, using both young pigs and also mature specimens, the whole carcass was boned and the entire vertebral column with the ribs attached, prepared for study. The flesh was first removed and the bones were then thoroughly scraped and cleaned so that the different vertebrae could be identified. In this way over 400 vertebral columns, varying in number of ribs from 13 to 17 inclusive, were examined. The results appear in table 2.

It will be noticed (see table 2) that the Cervical and Sacral vertebrae remain constant, that the Thoracic varies according to the number of the ribs while the Lumbar variation is from 6 to 7 except in the two cases where there were only 5 lumbar vertebrae present.

It would appear that usually the increase in lumbar vertebrae is associated with the smaller number of ribs present and vice versa.

TABLE 2. *Illustrating variations found in cervical, thoracic, lumbar and sacral regions of the vertebral column. The coccygeal vertebrae were not included.*

No. of Pigs	No. of ribs	Cervical Vertebrae	Thoracic Vertebrae	Lumbar Vertebrae	Sacral Vertebrae
1	13	7	13	7	4
29	14	7	14	6	4
25	14	7	14	7	4
234	15	7	15	6	
18	15	7	15	7	
116	16	7	16	6	
2	16	7	16	7	4
2	17	7	17	5	4
427					

Note: 300 of these pigs were purebred Yorkshires, the balance being grades secured at the abattoirs.

As the work progressed it became increasingly evident that the variation did not confine itself to unrelated pigs but was found quite as often among litter mates. Table 3 gives the result of a study of ten representative litters of purebred Yorkshires:

TABLE 3. *Showing variations among litter mates.*

No. of litter	No. of pigs in litter	RIB NO. 14	14+	15	15+	16	16+	17
I	13	6	1	6				
II	12	5		5	1	1		
III	12	1		11				
IV	12	1		11				
V	12			6		5		1
VI	10	3		6		1		
VII	8					7		1
VIII	14	3		8		3		
IX	10			3		7		
X	12			9	1	2		
	115	19	1	65	2	26		2
Percentage		16.52	0.87	56.52	1.74	22.61	0.0	1.74

The litters used in above table were pure bred Yorkshires from the University of Saskatchewan herds. No normal litters were found where all pigs possessed the same rib number. Several very small litters comprising 2 to 4 pigs were examined, where all pigs had the same number of ribs, but such were not considered normal and were not included in the table. A study of this table shows (a) that there is a variation in the number of ribs in all litters, (b) that the occurrence of rudimentary or floating ribs is rare and (c) that the percentage of sixteen ribbed pigs is very high.

To compare pigs of the different breeds studied a table showing the percentage of variation has been prepared, only those groups where 200 or more animals appeared being used. Percentages in cases where only a few pigs were studied would be obviously unreliable.

TABLE 4. *Percentages in groups where more than 200 animals were studied.*

Breed	Total Pigs Counted	RIB NO. 13	13+	14	14+	15	15+	16	16+	17
Yorkshire	678			13.86	0.29	57.96	2.07	24.93	0.15	0.75
Yorkshire × Landrace	374	2.94		49.47		37.17		9.89		0.53
Duroc-Jersey	484		0.21	36.16	4.96	50.83	2.68	5.16		
Poland China	839		0.38	37.88	7.51	47.32	2.98	3.93		
Chester White	642	1.40	0.16	48.91	11.06	35.98	1.56	0.93		
Hampshires	275	0.37		44.0	4.0	43.63	3.27	4.73		

Although the percentage in the above table cannot be accepted as final, it apparently is quite evident that the Yorkshire easily leads all other breeds in the number of ribs.

To find out if sex is correlated in any way with number of ribs 274 Yorkshire carcasses were carefully checked and the results tabulated as follows:

TABLE 5. *Sex and its relationship to rib count.*

Sex	RIB NO.					Totals
	13	14	15	16	17	
Males	0	16	88	37	1	142
Females	0	12	75	43	2	132

The results tabulated above make it quite clear that no relationship exists between sex and number of ribs.

SUMMARY

Although the foregoing investigation is not complete, since very small numbers of certain pure breeds have been examined, yet from the results obtained we feel that the following points have been established:

1. That the number of ribs in the pig varies from 13 to 17 pairs inclusive.
2. That rib variation occurs in all breeds.
3. That litter mates frequently appear to possess a greater degree of uniformity than unrelated animals, yet no single instance of complete uniformity has been observed by us among litters of normal size.
4. That additional ribs are definitely associated with the larger breeds and particularly those types known to possess heavy bone.
5. That the lesser number of ribs is definitely associated with breeds and types that are known to be small or of medium size and are recognized as fine boned types.
6. That the cervical vertebrae are constant in number.
7. That true ribs are always attached to thoracic vertebrae.
8. That the thoracic vertebrae vary according to the number of ribs present.
9. That the usual variation in the Lumbar vertebrae is from 6 to 7, only two specimens being found with 5.
10. That there is no correlation between sex and number of ribs present.

More work is now in progress at the University of Saskatchewan with a view to finding out whether or not additional numbers of ribs are of economic importance. The evidence so far strongly supports such a view. The question of developing pure strains possessing uniformity of rib number is also receiving attention. If this can be done the economic importance of additional pairs of ribs can easily be ascertained.

ACKNOWLEDGMENT

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THE CALCIUM AND PHOSPHORUS CONTENT OF SOME QUEBEC HAYS

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During the months from December, 1928, to February, 1929, inclusive, samples of hays were collected by Professor A. R. Ness of the Animal Husbandry Department of Macdonald College and brought to this laboratory as soon as collected. These samples were, for the greater part, collected stalk by stalk from the hay-mow, with the points in mind of getting as representative a sample as possible from each farm visited and of preserving intact the leaves and blooms. The samples were carried in "10 pound" paper bags. Below is tabulated the source of each sample together with the remarks tendered by Professor Ness as to its quality, condition, etc.

Table 1.

Sample Number	Nature	Source	Remarks
T1	Timothy	T. H. Barton, Vankleek Hill, Ont.	"In fair condition, some loss due to shattering."
T2	"	Ste. Sulpice Farm, Oka, Que.	"Slightly weathered".
T3	"	Ste. Marie Farm, Macdonald College,	"Excellent quality and well cured".
T4	"	LaTrappe Farm, LaTrappe, Que.	No remarks.
T5	"	Stock Farm, Macdonald College,	"Very leafy, well cured, coarse, grown on muck soil".
T6	"	Raymondale Farm, Vaudreuil, Que.	"Fine quality hay with heads and leaves in good shape."
T7	"	Maxwelton Farm, Baie d'Urfe, Que.	"Sample dry, some heads and leaves broken."
T8	"	James West, Howick, Que.	"Grown on heavy clay soil."
T9	"	J. W. Logan, Howick, Que.	"In excellent condition, clean and well cured, heads and leaves intact."
C1	Red Clover	Ste. Marie Farm, Macdonald College,	"Some leaves lost, over ripe."
C2	" "	Ste. Sulpice Farm, Oka, Que.	No remarks.
C3	" "	Maxwelton Farm, Baie d'Urfe, Que.	"Very dry, some heads off."
C4	" "	James West, Howick, Que.	"Very dry, heads quite intact but some leaves missing, probably aftermath."

It is significant to note that while samples of both clover and timothy hays were asked for at each farm, in only four cases was it possible to obtain clover. The scarcity of clover hay may be due to the inclemency of the past few winter seasons, to the poverty of the soils, or to other causes.

These hay samples were analyzed by the writer for calcium and phosphorus. They were obtained from some of the best farms in the vicinity and should be as well supplied with these two mineral elements as any timothy and clover hays obtainable in Quebec.

Methods of Analysis

Grinding. The entire samples, as received, were cut up into two inch lengths with a pair of scissors and put through a meat grinder to reduce the

material to shorter lengths. Then this was ground in a Merker mill until all passed a ½ mm. mesh sieve. Although this took upwards of five hours for each sample it was the only possible method which would yield a homogeneous product with the equipment at hand. The stems of the timothy hays were found especially difficult to grind and the sifting of the clover samples was also found to be troublesome. In the latter case, small iron objects, such as nuts and bolts, placed in the sieve with the sample, were found to be absolutely necessary. At the start of the work only mixing of the sample on a sheet of paper with a spatula was thought necessary but difficulty was experienced in getting similar weights of ash from different 15 gram portions of the same sample. Thereafter the sample was placed in a four litre wide mouth bottle and shaken and rolled to ensure perfect homogeneity.

Moisture. Moisture was calculated from the loss in weight of a 2 gram sample dried at 100°C. for 24 hours at atmospheric pressure.

Ash. The ash of the timothy hay was calculated from the loss in weight of a 15 gram sample ignited and kept at 600°C. in a platinum dish until constant weight was reached. In the case of clover hay 2 gram samples were ashed in this way.

Calcium. The ash residue was transferred quantitatively to a 250 cc. beaker with 10 cc. of 6M HCl and hot water, evaporated to dryness, and after adding 10 cc. more of 6M HCl was evaporated to dryness and dehydrated at 120° to 140°C. in a hot air oven for 30 minutes. The residue was then digested with 20 cc. of 3M HCl, filtered through a No. 41 Whatman filter paper and the undissolved siliceous residue washed with 0.1 M HCl. To the filtrate was added 5 cc. of N $FeCl_3$ solution and then 15M and 3M NH_4OH was added until neutral. The solution was boiled gently for a few minutes and filtered through a No. 41 Whatman filter paper, the precipitate being washed and then dissolved in 10 cc. hot 6M HCl. This solution was made up to about 50 cc., neutralized with 15M and 3M NH_4OH, boiled, filtered, the precipitate washed as before, and the filtrate and washings added to the previous ones. To the combined filtrates was added an excess of 0.25M ammonium oxalate and the whole left to stand over night after one hour digestion at the boiling point. The precipitate of calcium oxalate was filtered off on a No. 3 Whatman filter paper and washed well with hot water to which a little ammonium oxalate had been added. The filter was then broken so that the precipitate could be washed with water into the original beaker. The filter paper was washed with 10 cc. of hot 6M HCl and then with hot water until the washings were no longer acid. One cc. of ammonium oxalate was added to the filtrate and washings, which were then neutralized with about 10 cc. of 6M NH_4OH. After boiling for 1 hour the precipitate was allowed to stand over night. The purified calcium oxalate precipitate was filtered as before, washed with hot water, and when the filter paper had been broken, washed into the original beaker with more water. The paper was washed first with 5 cc. of hot 25 per cent sulphuric acid and then with hot water until the washings were no longer acid. The volume was made up to 50 cc., the solution heated to 70° to 80°C. and

titrated immediately with standard $KMnO_4$ of such strength that 1 cc. was equivalent to about 1 milligram of calcium.

The potassium permanganate solution was standardized before each set of determinations. Known amounts (from 50 to 150 mgs.) of pure sodium oxalate were weighed directly into 150 cc. beakers, 45 cc. of hot water and 5 cc. of 25 per cent sulphuric acid added, the solution heated to 70 to 80°C. and titrated immediately. A simple calculation gave the calcium equivalent to 1 cc. of the permanganate solution.

Phosphorus. The method used in the estimation of phosphorus was in part that of the Association of Official Agricultural Chemists (*1*) and in part a modification recommended by Fales (*2*).

In the method employed 5 gram samples of both timothy and clover hays were evaporated to dryness repeatedly with a solution of magnesium nitrate, ignited, and after taking up with 5 cc. of 16M HNO_3 and 50 cc. of water, again evaporated to dryness and ignited. The ash at this point should be completely free of organic matter and completely soluble in HCl. The ash was taken up with 10 cc. of 12M HCl, diluted to about 30 cc. and boiled to effect complete solution. The solution was made slightly alkaline with 15M NH_4OH and the precipitate just redissolved with 16M HNO_3. Fifteen grams of ammonium nitrate and 40 cc. of ammonium molybdate reagent were added and the whole digested at about 65°C. for one hour. The precipitate of ammonium phosphomolybdate was filtered off on a No. 2 Whatman filter paper and washed with 10 per cent ammonium nitrate solution. The precipitate was then dissolved with 10 cc. of 6M NH_4OH and washed through into the original beaker with hot water, the final volumes not being over 100 cc. The solution was then made neutral to methyl red with 16M HNO_3 and 10 cc. of magnesia mixture added, drop-wise, with constant stirring. After allowing it to stand for 15 minutes the solution was made 1.5N in NH_4OH by adding 15M NH_4OH and left to stand over night. The precipitate of magnesium ammonium phosphate was filtered on a No. 40 Whatman filter paper, washed with 1.5N NH_4OH, redissolved in 5 cc. of hot 6M HCl and washed through into the original beaker with hot water. The solution was made neutral to methyl red by adding 6M NH_4OH. The volume was then made up to about 50 cc. and 5 drops of magnesia mixture with 5 cc. of 15M NH_4OH added. The precipitate was allowed to stand over night. It was in this work weighed directly as magnesium ammonium phosphate by filtering it on an asbestos mat in a Gooch crucible which had been previously washed with alcohol and ether, dried by suction on a suction funnel for 10 minutes and allowed to stand for 20 minutes before weighing. In the crucible the precipitate was washed with 1.5N NH_4OH, with alcohol and with ether, and allowed to stand in the suction funnel for 10 minutes and in the room for 20 minutes longer before weighing again. It was found possible to filter, wash and weigh 12 precipitates in 3 hours.

Apparatus

Merker Mill. A Merker mill was used, driven by a ½ h.p. motor. About 15 grams of the cut up sample were placed in the bowl, then the grinding head was lowered and turned at a fairly slow rate of speed until

a metallic grinding sound was noticed. The bowl was then removed and after emptying its contents on to a sheet of paper, the grinding surfaces were removed and brushed clean with a small wire-haired brush. This operation was repeated until the whole sample would pass a ½ mm. mesh sieve. In some cases disintegration of the sample was most rapid when the pestle was raised and lowered slightly while in motion.

Constant temperature bath. The precipitate of ammonium phosphomolybdate that settles out at about 65°C. is of a dense crystalline nature, while that which separates out at room temperature is amorphous, finely divided, and difficult to filter because of its tendency to creep. For this reason a constant temperature bath, Fig. 1, was designed and built which would hold a temperature of about 65°C. The bath consists of a U-shaped galvanized sheet iron vessel with hollow side walls and bottom in which boiling methyl alcohol, B.P. 66°C., and its vapour, is kept. At each side is a water-cooled reflux glass condenser. The bath is surrounded on the sides with a wooden frame which lends to it support and rigidity and some degree of heat insulation. In the inner portion is placed about 1½ inches of water covered with a film of kerosene oil to prevent evaporation and a resulting drop in temperature. Heat is supplied from three Argand burners. The total cost of materials and labour used in making the bath was about $12.00.

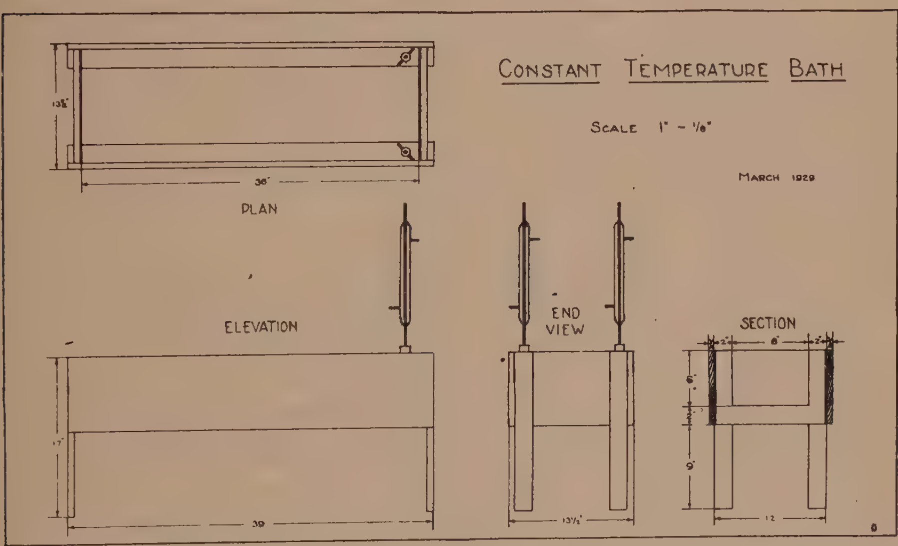

FIGURE 1.

Tests run on this home-made constant temperature bath show that after 25 minutes from the time of lighting the Argand burners, the water in the inner section is raised from about 20° to about 63°C. and that this temperature may be held for any length of time. The variation of temperature at different points inside the bath is only about 1°C. The apparatus

is a highly satisfactory arrangement, is cheap and very little trouble. A bath similar to this in principle is described elsewhere (*3*).

Results

In table 2 are given the percentages of moisture, ash, calcium and phosphorus in the samples as received. They are calculated to the air-dry condition from the results of at least two determinations and in some cases three. They have not been calculated to the moisture-free basis because of the similarity of moisture content and the fact that the figures given show the value of the hay as fed.

Table 2.—*The calcium and phosphorus content of timothy and red clover hay*

Nature of hay	Sample Number	Moisture	Ash	Calcium (Parts per 100)	Average	Phosphorus	Average
Timothy	T1	7.32	4.75	0.203, 0.207, 0,205	0.205	Not sufficient sample	
	T2	6.64	3.72	0.144, 0.141	0.143	0.134, 0.136	0.135
	T3	8.03	4.38	0.109, 0.107	0.108	0.089 —	0.089
	T4	6.84	4.56	0.095, 0.090	0.093	0.088, 0.095	0.091
	T5	6.74	3.94	0.076, 0.074	0.075	0.121, 0.117	0.119
	T6	6.63	6.17	0.091, 0.093	0.092	0.143, 0.138	0.140
	T7	7.86	5.28	0.092, 0.094, 0.091	0.092	0.082, 0.080	0.081
	T8	8.22	4.82	0.038, 0.042	0.040	Not sufficient sample	—
	T9	8.69	5.71	0.051, 0.058	0.055	0.177, 0,179	0.178
Red Clover	C1	6.78	5.59	1.225, 1.230	1.227	0.133, 0.135	0.134
	C2	8.70	6.69	0.993, 0.980	0.986	0.199, 0.191	0.195
	C3	8.45	6.88	1.140, 1.147	1.143	0.161, 0.165	0.163
	C4	8.97	5.88	0.968, 0.933	0.950	0.149, 0.149	0.149

Criticism of A.O.A.C. Method for Determining Phosphorus in Hays

The method for the estimation of phosphorus given in the A.O.A.C. "Methods of Analysis" (*1*) proved unsatisfactory with such forages as timothy hay. Criticism of this method is proffered. There is a large amount of organic matter that must be destroyed. The more practicable methods for its destruction are limited to magnesium nitrate fusion. Evaporation to dryness with HNO_3 or a mixture of HNO_3 and HCl resulted in a gummy mass of organic oxidation products which during the process of evaporation tended to foam over with resulting loss of sample. The addition of small amounts of potassium chlorate to a hydrochloric acid solution of the sample proved unsatisfactory because of the constant care and attention required. The use of perchloric acid as recommended by Fabry (*4*) for destruction of organic matter results also in gummy products and it is dangerous. A method not tried was one which employs the oxidizing effect of $NaNO_3$ with hot concentrated sulphuric acid in a Kjeldahl digestion flask. This method has been used by Richards and Godden (*5*) in the analysis of biological materials.

With magnesium nitrate solution about 25 cc. must be used in place of the 5cc. recommended in the A.O.A.C. "Methods of Analysis" and the mixture should be diluted to 200 cc. with water, boiling to dryness at least three times before attempting a fusion. With the first three series of

samples, the mixture was not diluted and on evaporating to dryness an explosive mixture resulted. This on detonation would throw the contents of the beakers a considerable distance from the hot plate. In the first of the three series the samples had been wetted with alcohol to aid in the mixing of the material with the magnesium nitrate solution. This at the start was thought to be the cause of the trouble. The second series was attempted without the addition of alcohol, with the same results. It was then suspected that the amount of magnesium nitrate solution was not sufficient and that it might be required in excess. The third series was therefore evaporated to dryness with 30 cc. of the reagent but still the samples were lost. With the dilution method, which has been described, that was afterwards practised, the evaporation has to be performed in 250 cc. beakers which are apt to crack during the ignition. Losses of samples also occur due to "spattering" when they were approaching the dry state for the first time, or from sudden ignition and "blowing".

For these reasons no two determinations of phosphorus on the same hay were made in any one series; the figures given are for repetitions and not duplicates in the same series. A promising method of fusion not tried until after the virtual completion of the work is the fusion of the sample with about 20 gm. of hydrated ferric nitrate. On evaporation when this method is used, no spattering takes place. Ignition occurs quietly. The subsequent solution in nitric acid might be treated by any one of the usual procedures for the estimation of phosphorus in iron or iron ores. The method seems promising, both for its economy in time and its possible guarantee of freedom from loss of samples.

In the course of the determinations it was noticed that at certain stages precipitates occur which are not entirely soluble in the next solvent. This is true of the ammonium phosphomolybdate precipitate and the first of the magnesium ammonium phosphate precipitates, both of which are found to yield a siliceous residue when dissolved in NH_4OH and HCl respectively. The beautifully crystalline nature of the second magnesium ammonium phosphate precipitate makes it doubtful, however, that there can be more than a mere trace of silica present. The dissolved silica may perhaps be the cause of a slow rate of filtering noted in many cases. Solutions of the clover samples, which contain less silica than the samples of timothy, are much more easily filtered.

Discussion

From an examination of table 2 it is evident that there is a considerable variation in the calcium and phosphorus content of both the clover and timothy hays. The percentage of calcium in the timothy hays varied from 0.04 to 0.20 and the percentage of phosphorus from 0.08 to 0.178. The results may be affected by the nature of the soils upon which the crops were grown, by the stage of maturity of the plants when cut, or by the treatment which the hay received after curing. As an example of the variation which may occur in plants grown on the same soil but receiving different amounts of phosphoric acid, table 3 is quoted (*6*).

A point in the results which is of interest is the fact that timothy hay is fairly well balanced between total calcium and total phosphorus.

TABLE 3. *The effect of added phosphoric acid on the phosphoric acid content of plants.*

Plant	Number of Samples	Percentage of P_2O_5 in Fertilizer	Plant
Oat	16	0	0.284
	10	4	0.283
	24	10	0.364
	4	16	0.442
Soybeans	12	0	0.452
	12	4	0.509
	12	10	0.521

Clover hay, on the other hand, is about ten times as rich in calcium as in phosphorus. Some other analyses of clover and timothy hays reported in the literature are given in table 4. Comparing these results with those obtained in this work, it may be concluded that seven out of the nine timothy hays are deficient in calcium and that clover hays are about normal in the content of both calcium and phosphorus.

TABLE 4. *The colcium and phosphorus content of timothy and red clover hays.*

Hay	Parts per 100 Calcium	Phosphorus	Source (Literature cited)
Timothy	0.192	0.123	(7)
	0.178	0.135	(8)
	0.266	—	(9)
	0.186	—	(9)
Red Clover	1.236	0.259	(7)
	1.142	0.170	(8)
	1.036	0.21	(6)
	—	0.43	(6)

SUMMARY

The calcium content of nine timothy hays grown in this vicinity has been found to be from 0.04 to 0.205 per cent. The calcium content of four clover hays was from 0.950 to 1.227 per cent. The phosphorus content of six timothy samples varied from 0.08 to 0.17 per cent and the phosphorus content of the four clover hays, from 0.134 to 0.193 per cent.

A criticism of the official method of the Association of Official Agricultural Chemists for the determination of phosphorus in forage crops is proffered, also a description of a convenient and cheap constant temperature bath for use in such determinations.

ACKNOWLEDGMENT

In conclusion I wish to acknowledge my indebtedness to Dr. R. R. McKibbin who in helping with the designing and obtaining of the constant temperature bath and in directing the work, was of great assistance, and also to Professor A. R. Ness for his care and trouble in getting the samples.

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THE EFFECT OF FERTILIZERS UPON THE FORMS OF PHOSPHORUS AND THE AMOUNTS OF PHOSPHORUS, NITROGEN, AND SILICA IN HAYS.*

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INTRODUCTION.

The compounds of phosphorus in forage plants and grains have been studied extensively during the past 25 to 30 years. In the main this study was confined to the isolation and qualitative study of the phosphorus in organic combination, with some quantitative study of the inorganic and organic fractions in plants. It is with this latter phase of study and methods for determining the same, combined with the variations in these two fractions under various fertilizer treatments, that the present work is concerned.

It is well known that phosphate fertilization of a phosphorus deficient soil causes a marked increase in the phosphorus content of the crops grown upon that soil. However, relatively little exact information is available as to whether or not this increase in phosphorus content is in the organic form or as inorganic phosphates or how the ratios between these forms will change. Accordingly, because of the increasing tendency to use phosphate fertilizers, it seems desirable to make a study as to how much fertilization affects the forms of phosphorus in the plant.

The work was made possible by the assistance of the Soils Department of Minnesota in furnishing a part of the samples used. Work has been carried on for some time by this Department on a low phosphorus peat soil, using as test plants a mixed crop of alsike clover and timothy. The peat soils plots had sufficient lime and potash, and the plots were treated with increasing applications of phosphorus. This work had shown an increase of total phosphorus content of the hays which was related to the magnitude of the phosphate fertilizer application.

HISTORICAL.

It will be necessary to review in some detail the more important publications, on the organic and inorganic fractions of phosphorus in plants, with special reference to the methods of separating the two fractions.

Plimmer (*33*) lists five groups of organic phosphorus compounds in plants:

1. Phytin, an inositol phosphoric ester, probably a calcium magnesium salt of the ester.

2. Phospholipines, lecithin being an example where the phosphorus occurs as a glycerol ester.

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3. Hexose phosphate, in which a hexose molecule is combined with phosphoric acid.

4. Nucleic acid, in which again a carbohydrate is combined with phosphoric acid and attached to the carbohydrate as a purine base.

5. Phosphoprotein, where the phosphorus is present in some form as yet unknown.

Phytin. In 1895 Palladin reported this compound discovered by him in his work on *sinapis niger*, describing it as a substance soluble in cold water, but insoluble in hot water, rich in phosphorus, containing calcium and magnesium but no nitrogen. He did very little with the compound except mention it, and it remained for Posternak (*34, 35, 36*) to conduct the first real investigation on the compound, and to give it the name phytin. He prepared phytin from a number of sources such as wheat, rape, corn and potatoes, stating that in grains where there is a small percentage of mineral phosphate, phytin forms 70-90 per cent of the total phosphorus, and that phytin exists as a storage reserve material for the supply of available phosphorus to the young embryo.

Subsequent to the study by Posternak (*36*) a good deal of interest was shown by many European workers in the organic phosphorus compounds of plants, without any real contribution to the identification of phytin, and in a resumé on organic phosphorus compounds Rose (*43*) reviews the literature and discusses some of the beliefs that were advanced regarding these compounds. He concludes that many of the statements of the earlier investigators were more or less conjectural, but that undoubtedly inosite phosphoric acid esters play an important rôle in the higher plants.

Forbes (*19*), in connection with the study of the rôle of the various phosphorus compounds in animal nutrition, reviews fairly completely the work previous to 1914 on the various organic compounds of phosphorus and also the methods used in separating the organic and inorganic fractions. The conclusions of early investigators were not always in accord as to the percentage of phytin in the different plants, due mainly to inaccurate methods of determining it. Neither were they agreed as to the use of phytin in the metabolism of the plant.

A good deal of controversy existed as to whether Posternak (*36*) had given a true description of phytin, and Anderson (*5*) gives a review of his attempt to determine the structure of phytin, and to synthesize it. He tried to isolate the compound as the salt of some of the heavy metals from such substances as wheat bran, cottonseed meal, oats and corn. Throughout most of his earlier work he obtained two compounds, the mono-and triphosphoric acid esters of inositol*. He discovered that the enzyme phytase in much of his early work was instrumental in giving him split products of phytin, and he concluded that in extracting phytin from the grains, it was necessary to use a 1.0 per cent acid solution to prevent the enzyme action, instead of the 0.2 per cent hydrochloric acid solution used by former workers. Extraction with the weaker solution gave higher results for

*The word inositol has been generally accepted as the correct name of this compound, though inosite is used frequently in connection with the earlier work on these compounds.

inorganic phosphorus due to the splitting of phosphorus from organic combination by the enzyme phytase.

Rather (*39*), while working with the phosphorus compounds of cottonseed meal in which he considered that he had demonstrated the phosphorus to be entirely in organic combination, found that contrary to Anderson's statement, 0.2 per cent acid solution did prevent the action of phytase to a certain extent. The difference in the results of these investigators may have been due to buffers present in the extracting solution.

Boutwell (*9*), in extracting phytin from Indian mustard and wheat bran, used the method of Clark (*10*) in which 2.0 per cent hydrochloric acid was used for extraction, believing that the 1.0 per cent acid used by Anderson (*3*) did not exclude all enzyme activity.

Many formulae for the structure of phytin were advanced, and much disagreement over methods of preparation, but Kostytschew's (*28*) "Plant Physiology" gives the formula of phytin as a hexa phosphate of inosite, and gives Posternak (*37, 38*) the credit for establishing the true structure of the compound, and he says although phytin is spoken of as a phytochemical compound, a phytin synthesis in light has not been recorded.

Organic compounds other than phytin. Hexose phosphate for the present work may be disregarded as it is so easily hydrolyzed by acid that it would appear as inorganic phosphorus in the extract, if phosphorus were present in such form in forage. The remaining forms of phosphorus will be included in the phospholipines, nucleic acid, and nucleoproteins, and Forbes (*20*) has compiled most of the information before 1914 on these forms of phosphorus in hays.

The data on the nucleic acids and nucleoproteins are listed under different headings due to the fact that it was impossible to ascertain in just what form these exist in the plant. Some authors speak of protein phosphorus, others of nuclein phosphorus, but in the main it may be taken to mean the inert organic phosphorus remaining after deducting the phytin and phospholipine phosphorus fractions.

Fraps and Rather (*21*) investigated the ether extract of several kinds of hay, straw and other roughages. The phosphorus content of the ether extract was taken to represent the phosphatid content of the products. Their results show the lecithin phosphorus content to be extremely low in these fodders.

From a review of the literature on phosphorus compounds it would appear that the phytin fractions and the nuclein or nucleoprotein fractions are the major portions of phosphorus in the organic form that must be considered in this work on hays. There is a possibility of some phosphatid phosphorus being present but it will, in all probability, be small in amount.

Forbes (*19*) in his work on a method for separating the various forms considers only the three fractions, protein phosphorus, phytin, and the inorganic portion. Of these three phytin seems to be found in larger quantities in the seeds of most plants but does not occur to any appreciable extent, in comparison with the nucleoproteins and inorganic phosphorus, in the forage crops.

The differentiation of the organic and inorganic phosphorus. In the earlier work on plant phosphorus the main interest was the organic portions, particularly phytin phosphorus, and less interest was shown in the determination of the inorganic fraction. However, though many of the investigators report inorganic phosphorus, very few of them agree on methods for its determination.

Plimmer (*33*) among the first investigators, used a solution of magnesium citrate to precipitate the inorganic phosphorus as the magnesium ammonium phosphate. This method, however, was later shown to be incorrect in the presence of phytin which is also precipitated by the magnesium citrate solutions. Direct precipitation by ammonium molybdate solution at 65°C. in the presence of dilute nitric acid was used by Hart and Andrews (*23*). The dilute acid was used as a precaution against the hydrolysis of some of the organic forms of phosphorus by the acid. McCollum and Hart (*29*) and Patten and Hart (*31*) also used this method, but here again it was shown that phytin interfered, inhibiting the precipitation of the yellow compound and the organic matter also present in these extracts helped increase the error.

A microchemical method was employed by Hartwell and Hammett (*25*) on turnips in which they added magnesium sulphate and ammonium chloride to a section of the turnip and studied the crystals formed, estimating the phosphorus in this manner. They checked their method against the precipitation by both magnesium mixture and ammonium molybdate and finally concluded that the two latter methods included in the precipitation a part of the organic fraction.

A method in which the inorganic phosphorus was first precipitated by magnesium mixture, then re-dissolved in nitric acid and the phosphorus precipitated with ammonium molybdate and finally determined as the magnesium pyro-phosphate, was used by Vorbrodt (*49*); the inorganic and organic fractions of phosphorus reported by Suzuki and Yoshimura (*46*), Suzuki, Yoshimura and Takaishi (*47*), and Heubner and Rieb (*26*) were determined by some modification of the above methods. The use of acid alcohol, later employed by Forbes, was introduced by Stutzer (*45*).

Forbes and associates (*18*) studied in detail methods for the separation of inorganic phosphorus. They decided that the method used by Hart and Andrews (*23*) was the most specific starting point for further work, and they criticized the method on the following accounts:

1. The time for extraction used by Hart, which was fifteen minutes, was not long enough to extract all the inorganic phosphorus.

2. Ammonium molybdate in neutral solution was found to give poor precipitation, leaving part of the inorganic phosphorus in solution.

3. The bulky flocculent precipitate forming, gave trouble and it was often difficult to know whether or not precipitation was complete.

4. The precipitate was found very difficult to filter.

5. The method involves the precipitation of inorganic phosphorus in the presence of phytin. A quantitative precipitation of inorganic phosphorus alone from a solution containing phytin appears to be impossible.

6. Nucleinic acid may be hydrolyzed by the nitric acid in this precipitation, the result being the formation of inorganic from organic phosphorus.

7. Nucleinic acid, like phytin, appears to hinder the formation of the yellow precipitate.

8. Another possible error is the carrying down of phosphorus containing proteids with the yellow precipitate.

In the work previous to this paper of Forbes, the extracting solution generally used was 0.2 per cent hydrochloric acid. Forbes found this satisfactory but lengthened the time of extraction to three hours. Magnesia mixture was used to precipitate the inorganic phosphorus and the phytin from the extract solution, the nucleinic acids remaining in solution as they are soluble in ammonium hydrate. This precipitation also removes part of the bulky precipitate. The inorganic phosphate was then dissolved from the magnesia mixture precipitate by the use of acid alcohol. This acid alcohol was believed to leave the phytin in the precipitate and remove the inorganic phosphate. Phenol was employed to prevent enzyme action on the phytin.

Experiments were carried out to see if phytin or nucleinic acid would decompose in 0.2 per cent hydrochloric acid. They were unable to demonstrate any decomposition in this reagent in either 3 or 24 hours extraction.

Plimmer (*33*) carried out some work previously on the decomposition of these compounds in different strengths of acids. He states that glycerophosphoric acid is slowly hydrolyzed by dilute acid, complete separation of the phosphoric acid requiring ten days at 92°C. Phytic acid was found to be the most stable of the organic phosphorus compounds. At 37°C. dilute acid causes no hydrolysis; at 64°C. a slight hydrolysis could be detected in 24 hours. Hexose phosphate was found to be easily hydrolyzed. Nucleic acid was found to be hydrolyzed by acid, normal hydrochloric producing complete hydrolysis in eight days at 75°C.

These results indicate that there is little danger of the organic compounds of phosphorus undergoing any hydrolysis in an extracting solution as concentrated as 1.0 per cent hydrochloric acid.

The final method adopted by Forbes and associates was:

1. Three hours extraction with 0.2 per cent hydrochloric acid.

2. Precipitation of the inorganic phosphorus and phytin by adding magnesia mixture and NH_4OH, and allowing to stand over night.

3. Filtering the above precipitate and washing it with 2.5 per cent NH_4OH and then with 95 per cent alcohol until free of ammonia.

4. The inorganic phosphorus was dissolved from the precipitate with 95 per cent alcoholic solution containing 0.2 per cent hydrochloric acid, filtering and precipitating the inorganic phosphorus with ammonium molybdate, finally determining it as the pyrophosphate.

The above method was employed by Ames and Boltz (*2*) in some work on the phosphorus fractions in alfalfa hay, and also by Rather (*41*, *42*) who used 5 per cent phenol solution to prevent enzyme action.

Following the work of Forbes and associates on this method, Collison (*11*) suggested a method in which he proposed using an acid alcohol solution for the extraction of the inorganic phosphorus. The method would

prevent enzyme action but he would still have the difficulty of separating the phytin, phosphatid and inorganic phosphorus compounds. He states that the method is not proposed as a perfect means for this analysis but he proposes it as an improvement on some of the others. He is the only person in the literature using this method so it can not have proven a success.

Anderson (*4*), after publishing a large amount of material on the mono- and tri-phosphoric acid esters of phytin, decided to carry out some work on the effect of phytase, and in this connection he ran some inorganic analyses. He found the enzyme very active in 0.2 per cent hydrochloric and he increased his extraction solution to from 0.5 to 1.0 per cent hydrochloric acid, at which concentration he found the enzyme was destroyed. He did not follow the Forbes method of precipitating the inorganic phosphorus with magnesia mixture but used the direct precipitation with ammonium molybdate and reported his results by this method.

Bodnar (*8*), in some similar work, used much the same method as Forbes, i.e. the precipitation by magnesia mixture, but he used 25 cc. of 8 per cent nitric acid in the cold to dissolve the inorganic phosphorus from the magnesia mixture precipitate. The remainder of the determination was carried out by the regular phosphorus method.

Some colorimetric work was carried out on the determination of phytin. Heubner and Stadler (*27*) used a method in which they determined phytin by treating the extract solution with a ferric chloride solution in the presence of ammonium thiocyanate. According to this method the phytin is precipitated from solution as the iron salt of phytic acid, the salt being very slightly soluble in the hydrochloric acid solution. When the phytin is removed from solution the excess iron gives an indication by reacting with the ammonium sulphocyanate.

Averill and King (*7*) used the above method in some determinations on oats, rye, wheat and soybeans. They used 2.0 per cent acid for extraction as they believed the enzyme phytase was still active in the 1.0 per cent acid solution and Rather (*40*) employed the same method on Kafir corn and cottonseed meal. Rather states that 97 per cent of the phosphorus of cottonseed meal is in organic combination in the form of phytin as determined by the Heubner and Stadler colorimetric method. The remaining three per cent was believed to be inorganic, being determined by the Forbes method, but Rather questions the accuracy of this method, and thought it best not to publish results based on it. In an attempt to employ the colorimetric method on the hays of soybean, cow pea, velvet bean and alfalfa, the colour of the extracted solution of these hays prevented the use of such a method.

A review of the literature shows a decided lack of some dependable method for the determination of inorganic phosphorus in vegetable substances.

The Assocation of Official Agricultural Chemists (*20*) took up the matter and they made Forbes chairman of a committee to consider methods for the determinations of inorganic phosphorus in plant and animal tissues. In the report Forbes outlines a method for the determination of inorganic phosphorus of animal tissues that he considered would do as an official method. It was a modification of his former method, but though he outlines

the attempt made on vegetable or plant inorganic phosphorus, he finally concludes that he is unable to recommend it or any other method as a standard method for this work and he gives as one of the main difficulties the separation of the inorganic fraction from the gummy magnesia mixture precipitate.

The Method.

Search for a method. In a review of methods it was hoped to secure one that would give at least comparative results, and that would prove short enough to allow the carrying out of the analysis, in a reasonable time, of the large number of samples collected for this work.

The great amount of work done on the phosphorus of blood, a problem which in a sense is parallel to the vegetable work, suggested the idea that some of the methods used in that work might be adopted, methods that would be more rapid and probably more reliable than the older ones.

The Fiske and Subbarow method (*17*) was therefore tried, using the Dubosque colorimeter, the only type of colorimeter available at that time. It was found, however, in all cases of a hay extract, that the yellowish red colour of the extract so changed the blue phosphorus colour produced as to make the reading of the colorimeter impossible. The yellow hay colour added to the blue phosphorus colour, gave the solution a decidedly green tinge. This was especially true in solutions low in phosphorus where the amount of extract had to be large in order to give colour enough for comparison.

Failing to find the above method applicable, the older methods were resorted to and a rechecking of these was undertaken to give a method best suited to this particular type of work.

Forbes' method (*18*) was first tried, using 1.0 per cent hydrochloric acid, instead of the 0.2 per cent used by him, the higher concentration being used to make certain no enzyme action occurred. The method as outlined proved unsatisfactory. The time for the magnesium mixture precipitation was increased from twelve hours to two days before precipitation seemed complete. The filtration proved slow and difficult and had to be carried out carefully under suction, care being taken at the beginning to allow the pores of the filter to fill before applying the suction; otherwise some of the precipitate was carried through the filter.

Results from the method as outlined by Forbes were unsatisfactory and it was believed at the time to be due to the difficulty as suggested by Forbes of dissolving out the inorganic phosphorus from the gummy precipitate.

Collison's (*11*) method of acid alcohol extraction was then tried, but it did not prove as easily handled as the Forbes method and was finally discarded.

Anderson (*3*), in his work on phytase, used a direct precipitation with ammonium molybdate, and believing from the work of Hart and Tottingham (*24*) that there probably was not much phytin in these extracts to interfere with the yellow precipitate, this method was tried. Poor results were obtained, however, as a muddy brown precipitate was obtained which proved very difficult to filter. The attempt was made to redissolve this first precipitate

in ammonia and precipitate again, but the second precipitation did not seem to reduce the errors in any way.

In connection with this method an attempt was made to determine the phytin phosphorus in the extract, using the Heubner and Stadler (*27*) method as used by Rather (*40*). The colour of the extract solutions was found to be too deep to allow for any accurate determination of end point, even if phytin were present, but practically no noticeable precipitate was obtained from the iron added.

Attention was finally turned to a study of the dissolving of the inorganic phosphorus from the gummy magnesium mixture precipitate in the Forbes method (*18*). First acid alcohol was tried, then dilute nitric acid, and finally an 8 per cent nitric acid was used from the method of Bodnar (*8*) as the means of giving the greatest uniformity of results.

A tentative method. The method finally adopted was as follows:

Extraction of a five gram sample of hay in 250 cc. of 1.0 per cent hydrochloric acid solution for three hours, the bottle container being placed in a shaker to keep the sample thoroughly distributed throughout the liquid.

The sample was then filtered through a gooch crucible and 50 cc. of the filtrate taken for analysis. 40 cc. of magnesium mixture was added and 20 cc. of concentrated ammonium hydroxide, and the solution was allowed to stand for 48 hours.

The solution was next filtered through a buckner, taking the precautions mentioned above of allowing the filter pores to absorb some of the precipitate before suction was applied. Qualitative filter paper was used as the quantitative was found to be almost out of the question, the material refusing to filter.

The precipitate was then washed with 2.5 per cent ammonium hydroxide, and finally some 95 per cent alcohol. The filter paper and precipitate were removed to an Erlenmeyer flask, 25 cc. of 8 per cent nitric acid added, and with a stirring rod the paper and precipitate were broken up as much as possible; then the mixture was occasionally shaken for a period of 20 to 30 minutes, the solution filtered, washing the precipitate remaining on the filter carefully with water.

The volumetric analysis for phosphorus was run on this filtrate in the ordinary way. This modification of the above methods was adopted for a time as giving the most uniform results.

Work was continued, using this method on the 1926 crop of mixed hay samples. Three fractions were determined, (1) the inorganic phosphorus by the method above described, (2) the total extract which includes the inorganic phosphorus plus some organic phosphorus, by evaporating the solution to dryness in an evaporating dish after adding some calcium acetate to the solution, then burning, and running the regular volumetric phosphorus determination on the residue, and (3) the total phosphorus of the hay sample by ashing with magnesium nitrate and running phosphorus volumetrically. This method, though giving fairly accurate results, was found to be exceedingly slow where a large number of hay samples were to be analyzed.

Following the summer of 1927, in which a large number of additional samples were taken for analysis, it was felt that some quicker method was

necessary if the work was to be accomplished in any reasonable length of time, so an attempt was again made to apply some colorimetric methods to the problem. A colorimeter was procured that was similar in construction to the Bausch and Lomb instrument in which two extra cups were attached to allow for compensation of colour that might be present in the solution being analyzed. By carefully adding some of the dilute extract solution plus a small amount of the ammonium molybdate solution used in the Fiske and Subbarow method (*17*) to the compensating cup, a reading of the solutions could be accurately obtained. This method was then introduced instead of the Forbes method previously used and the entire group of samples of both 1926 and 1927 analyzed by it.

The final method. The Fiske and Subbarow method depends on the fact that certain reducing agents will produce a blue compound with the ammonium phospho-molybdate compound, and this colour in the unknown is then compared with a standard solution.

The inorganic, total extract and total phosphorus fractions were run as before, but using the colorimetric instead of volumetric method.

Reagents for the Fiske and Subbarow Method. Molybdate solution No. 1: 2.5 per cent ammonium molybdate in 5 normal sulphuric acid. Dissolve 25 grams of the salt in 200 cc. of water. Rinse into a litre flask containing 500 cc. of 10 normal sulphuric acid. Dilute, make up to volume, and mix.

Molybdate solution No. II: 2.5 per cent of ammonium molybdate in 3 normal sulphuric acid. Dissolve 25 grams of the salt in 200 cc. of water. Rinse into a litre flask containing 300 cc. of 10 normal sulphuric acid. Dilute, make up to volume, and mix.

Amino napthol sulphonic acid 0.25 per cent: Dissolve 0.5 grams of the dry powder in 195 cc. of 15 per cent sodium bisulphite, add 5 cc. of 20 per cent sodium sulphite, stopper and shake until dissolved.

Standard phosphate solution: 5 cc. = 0.4 Mgs. P. Weigh out 0.3509 grams of pure monopotassium phosphate in water, add 10 cc. of 10 normal sulphuric acid and dilute to a litre.

The procedure in the method finally adopted was as follows: Shake 5 grams of hay in 250 cc. of 1.0 per cent hydrochloric acid for 3 hours. Take a portion of this extract, depending on the quantity of phosphorus in the material, place in a 100 cc. volumetric flask, dilute to 75 cc. add 10 cc. of molybdate II solution, mix, then add 4 cc. of the amino napthol sulphonic acid, shake and allow to stand 10 minutes, then dilute to the mark, mix and compare with the standard.

The molybdate II solution is used for the inorganic determination as it is lower in acid and hence is less liable to hydrolyse organic compounds, and the molybdate I is used for the standard and all samples where the organic matter has been removed.

Test of method for extraction and hydrolysis. Forbes (*18*), in his work on the method for inorganic phosphorus, decided that three hours was sufficient time for extraction of the inorganic and phytin fractions of phosphorus. Anderson (*4*) used the same period for his work on inorganic

phosphorus. In order to be certain that the time required for the extraction of inorganic phosphorus and phytin, used by Forbes and Anderson, was sufficient, when analyzing hay samples, it was deemed advisable to check the procedure. Alfalfa hay was used as being fairly typical of the hays and the time required for complete extraction, studied together with the effect of the acid solution on hydrolysis of the organic phosphorus fraction over different periods of time.

TABLE 1. *Inorganic P_2O_5 determined on five gram samples of alfalfa hay, extracted for different periods of time in 250 cc. of 1 per cent hydrochloric acid (per cent.)*

Samples	1 Hour	2 Hours	3 Hours	5 Hours	12 Hours	24 Hours	48 Hours
1	.52	.51	.52	.52	.52	.52	.58
2		.52	.52	.52	.52		
3			.51	.51	.52		
4				.51	.52	.52	.58
5					.52	.53	.57

Total Phosphorus in Extract = .639.

Phosphorus was determined on five sets of duplicate samples extracted for different periods of time, as shown in the above table The five sets of samples were placed on the shaker at the same time. Set No. 1 was removed at the end of 1 hour, set No. 2 at the end of the second hour and sets 3, 4 and 5 at the end of the 3 hour shaking period. Sets No. 1, 2 and 3 were analyzed for phosphorus as soon as removed from the shaker, and then set aside at room temperature and analyzed at the intervals shown in the above table. Sets No. 4 and 5, however, were not analyzed immediately on removal from the shaker, but were set aside at room temperature and analyzed at the intervals shown.

These data indicate that total extraction may be expected after 1 hour's shaking, the three hours used being sufficient, and that no hydrolysis of the organic portion occurs within 12 to 24 hours at least.

Since all subsequent determinations were carried out within an hour of their removal from the shaker, it seems safe to assume that there is no danger of hydrolysis.

Test of the method for the recovery of added inorganic phosphorus. The extract solution when evaporated and the residue ashed, gives a higher percentage of phosphorus than can be determined directly on the extract. It seems safe to assume from the work of Forbes and Anderson that the extract solution may contain a portion of the organic phosphorus. Experiments were carried out to prove that the part determined directly on the extract solution is inorganic phosphorus. For this purpose inorganic phosphorus was added to the samples in varying amounts, and the resulting solutions analyzed. Monopotassium dihydrogen phosphate was added in a one per cent acid solution. 250 cc. of 1.0 per cent acid solution were used for extraction and the additions of phosphorus added to the samples prior to the shaking, care being taken that the extracting solutions were in all cases 1.0 per cent acid solutions, regardless of the phosphorus added.

TABLE 2. *Recovery of added phosphate.*

	P_2O_5 Added Mgs.	Mgs. of P_2O_5 inorganic present in 1 gram of hay computed	Mgs. of P_2O_5 inorganic recovered from 1 gram of hay determined	Per cent of total P_2O_5 present recovered
Alfalfa	Check	6.63	6.63	100.
"	1.13	7.76	7.93	102.0
"	2.21	8.48	8.59	101.0
"	2.57	9.20	9.15	99.5
Timothy	Check	1.34	1.34	100.0
"	1.43	2.77	2.74	99.0
"	1.80	3.14	3.18	101.0

This experiment shows that the phosphoric acid added to a hay sample, going through the shaking or extraction, can be recovered in the inorganic fraction by the colorimetric method.

Plimmer (*33*) suggested that the phytin in the seed was present as the calcium magnesium salt, but that it was transported as the potassium salt. No one has attempted to suggest the form in which the inorganic fraction is held in the hay, but as even aluminum phosphate is soluble in 1.0 per cent hydrochloric acid, there is little question of the solubility of any inorganic form that may be present.

A comparison of the tentative volumetric method and the final colorimetric method. As stated above, the mixed timothy and alsike samples were run by the Forbes method and also by the colorimetric method and it is interesting to note the comparison of the two methods on the following samples:

Sample No. 1 is from light yielding check plots, No. 2 from heavy yielding check plots, Nos. 3, 8 and 7 from plots receiving 100, 500 and 2,000 pounds per acre respectively of phosphate fertilizer.

TABLE 3. *Comparison of the volumetric and colorimetric methods of analysis for phosphorus. (Per cent).*

Sample No.	Volumetric Method			Colorimetric Method		
	Total P_2O_5	Total Extract P_2O_5	Inorganic P_2O_5	Total P_2O_5	Total Extract P_2O_5	Inorganic P_2O_5
1	.70	.40	.26	.67	.45	.28
2	.61	.39	.27	.61	.33	.27
3	.72	.53	.41	.79	.52	.44
8	.92	.70	.54	.91	.71	.54
7	1.13	.82	.64	1.13	.80	.61

The two methods, though not showing identical results, check close enough to give in this type of work comparative results. There is no comparison, however, in the time and labour of the two methods, the colorimetric being by far the quicker method. It is also my belief that the colorimetric method yields far more accurate results. The range of variation between duplicate determinations is much closer when the colorimetric method is used.

Parker and Fudge (*32*), in their work on phosphorus, state that the Fiske and Subbarow method proved satisfactory in the determination of phosphorus on the acid extracts of soil; however, no mention is made of this method being used for total soil phosphorus.

In the above work on the phosphorus of hay, the colorimetric method, compared with the volumetric method, proved so much more rapid and accurate, that an attempt was made to modify the method in such a way that it might be used in the routine total soil phosphorus determinations.

A group of soil samples was analyzed by the two methods and it was found that the colorimetric method proved much superior in time required for the determinations; at the same time the duplicates gave better checks than obtained by the volumetric method, and the percentage phosphorus determined by the two methods gave comparative results. The colorimetric method proved so much more rapid with equal accuracy that we are now using it for total soil phosphorus in the soils laboratory.*

The routine procedure is as follows: Weigh out 4 grams of soil in a porcelain crucible, mix thoroughly with 4 grams of magnesium nitrate and heat slowly until the water of crystallization has been removed. The addition of a small piece of parawax will prevent bubbling while driving off the water. When dry, heat to 600°C. in an electric oven. Remove the contents of the crucible to a beaker and pulverize, rinse the crucible with 10 cc. of concentrated hydrochloric acid, and add to the sample in the beaker. Place the concentrated acid mixture on a steam bath, being careful that all the sample is moistened with acid, and digest for two hours. After the two hours on the bath add 25 cc. of distilled water and digest for 1.5 hours, again being careful that the soil mass is not adhering to the bottom of the beaker. Remove from the bath at the end of the second period and transfer the contents to a 200 cc. volumetric flask and make up to volume.

It is essential that care be taken to get all the iron into solution. If such care is not taken some of the iron may remain in colloidal solution and spoil the determination. As small a quantity of concentrated hydrochloric acid as will wet the sample is used, since too great a concentration of acid hinders the colour development later.

A sample (10 cc. to 50 cc. depending on the percentage phosphorus in the soil), usually 25 cc., is next transferred from the 200 cc. aliquot to a 100 cc. volumetric flask, add 10 cc. of molybdate I solution, and 5 cc. of the reducing solution, allow the colour to develop, make up to volume and compare in a colorimeter with the standard as described in the method on hay phosphorus.

Colour development may be retarded by the concentration of acid in some cases. This may be speeded up by raising the temperature 10°C. above the ordinary room temperature.

Problem.

The problem, as stated in the introduction, was the study of the variations in the inorganic and organic fractions of phosphorus in hays grown under different phosphate fertilizer treatments. A rechecking of methods employed in the analysis of the above fractions, established the fact that no satisfactory method existed for this type of work, and the work described under methods was performed, as a result of which a colorimetric

*University of Alberta.

method has been developed. The following experimental results were obtained by this method.

The work was originally started with the idea of studying the alsike-timothy crop on the peat land of Coon Creek Experiment Station, which showed decided increase in the percentage of phosphorus in hays under phosphatic fertilizer treatment as well as an increased yield of hay over the check plots.

Eckles, Becker and Palmer (*13*), in a bulletin on mineral deficiency of cattle, report a condition in cattle in Minnesota, also common in many parts of the world, that is believed to be due to some deficiency in the mineral portion of the ration; at least the condition found in Minnesota responds to the feeding of inorganic phosphorus, or high phosphorus hays. This condition in the State, along with the practice of growing hays on the peat lands, much of which is found by Alway (*1*) of the Soils Department to be low in phosphorus, led to the desire to see in what form these hays stored the phosphorus supplied in the form of fertilizer.

No experiments have been carried out that prove the ability of an animal to survive on an entirely inorganic phosphorus ration; however, it has been proven fairly conclusively that phosphorus supplied in the inorganic form to animals will suffice to overcome any deficiency of this element that may occur in the average diet. Without going into the discussion of whether organic or inorganic phosphorus is the better form of phosphorus for feeding, it would seem that if it could be proven that the increase in phosphorus in a pound of hay was entirely inorganic, it would be possible to advise the farmer to fertilize a field with an application of phosphorus heavy enough to produce his maximum paying crop of hay, and if this hay were found too low in phosphorus for a cattle ration it could be supplemented much easier and quicker by feeding the animal some form of inorganic phosphate directly. Phosphorus fed in this form would be the same to the cattle as phosphorus fed through a hay crop as inorganic phosphorus, and it would be a much cheaper method of getting it to the animals.

The phosphate hunger, according to Alway (*1*), is not by any means confined to the peat lands in Minnesota but is also found on the dark prairie soils of the West and Southwest, and the growing of hay on the latter soils is a problem somewhat similar to the one on peat in so far as they both respond to phosphate fertilization.

In dealing with hay samples such are used in this work, a study was made as nearly as possible of the forms of phosphorus as they exist in the average hay fed throughout the country. It is true that these may not be the forms in which it is to be found in a growing plant, but except in the case of pasture, the animal takes the phosphorus as it is provided in a hay, hay that is cured under various treatments and cut at various stages of its growth, and it is with such feeds that the farmer must deal in determining the ration for his stock.

The material. The data submitted consist of analysis of alsike hay and timothy hay grown on Coon Creek Experiment Station peat plots, rape from pot experiments on peat, alfalfa hay grown on the sandy upland

plots of Coon Creek, sweet clover, barley straw and wheat straw from Alberta wood soil pot experiments, and a set of upland native hay samples collected from both Alberta and Minnesota native hays. The alsike and timothy hay in 1926 was cut on Oct. 9th and analyzed as a mixed hay. The 1927 samples from the same plots, cut July 23rd, were separated and analyzed as individual samples. The alfalfa, cut May, 1927, was sampled about the time of the first cutting in Spring. Three set of samples of rape grown on peat, were used, two were early cuttings, collected when the plants had reached a height of 6 to 8 inches, the third were plants allowed to mature. The sweet clover, barley straw and wheat straw were supplied by the University of Alberta from experiments carried out on the fertilization of the podsolic wood soil.

Experimental data. The first three columns of the following tables give the amount of P_2O_5 in per cent reported to nearest second decimal in the three fractions, total sample, 1.0 per cent acid extract, and inorganic fraction. These percentages are based on the oven dried sample (100° in vacuum). The next two columns contain the phosphorus of first, the total extract, partly organic and partly inorganic, expressed as per cent of the total P_2O_5 of the hay, and second, the inorganic fraction expressed in the same way.

The organic P_2O_5 is expressed in terms of per cent of phosphorus in the hay, or in the same terms as the first three columns. These figures, expressed as per cent of total phosphorus, would be just the reverse of the inorganic columns so they are reported in such a way as to show the amount present per gram of hay.

Soluble organic and insoluble organic phosphorus have also been computed but these fractions show quite a variation between themselves and although they are given in the tables no discussion of them was considered necessary.

The data on the phosphorus fractions of mixed timothy and alsike hays grown in 1926 at the Coon Creek Experiment Station of the Division of Soils, subject to different phosphorus fertilization treatments, are given in table 4. These data indicate that under the increased phosphorus applications the inorganic fraction increased from 42.0 per cent of the total phosphorus on the check plots to 63.5 per cent on the fertilized plots. In the higher applications of fertilizer there is shown a slight increase of organic phosphorus, but hardly more than the general variations in this fraction, and this increase is shown on the plot with a 750 pound application of phosphate, the higher applications giving a slight decrease.

This hay is one that had gone through the entire season's growth, being harvested in October. The total P_2O_5 shows an increase of over 65 per cent, this increase being the difference between the check plot and the plot receiving the 750 pound application per acre of fertilizer.

The light and heavy checks mentioned in this table are two sets of check plots, those with the very light crop as light checks, and the heavy checks those with a better yield for some reason unknown. The heavy checks giving the greater number of pounds of hay are consequently somewhat lower in phosphorus per pound.

TABLE 4. *Phosphorus fractions on the mixed timothy and alsike hay from the Coon Creek Experiment Station,* 1926.

		Phosphorus fractions P_2O_5 (per cent).							
Sample No.	Pounds of phosphate fertilizer applied	Total*	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
1	Light checks	.67	.45	.28	67.5	42.1	.39	.17	.22
2	Heavy checks	.61	.33	.27	53.9	43.7	.34	.06	.28
3	100 lbs.	.79	.52	.44	65.6	56.0	.35	.08	.27
5	200 lbs.	.83	.59	.49	71.1	58.7	.34	.10	.24
8	500 lbs.	.91	.71	.54	77.5	59.5	.37	.16	.21
10	750 lbs.	1.07	.79	.63	73.8	58.8	.44	.16	.28
4	1000 lbs.	.95	.71	.61	74.4	63.6	.35	.10	.25
7	2000 lbs.	1.13	.80	.61	71.2	54.0	.42	.19	.24

*Rate for P_2O_5 reported only to nearest second decimal.

The timothy and alsike hay grown on the mixed alsike and timothy plots in 1927 was harvested in July and the two hays separated by hand. The increase in total P_2O_5 on fertilized plots over check plots in the timothy, see table 5, ranges from 85 to 100 per cent. The inorganic phosphorus increases from 42.0 to 64.0 expressed as per cent of the total phosphorus. The organic fraction shows an increase in the 1,500 pound per acre application of fertilizer, but no increase under the 200 pound fertilizer treatment. The amount of organic phosphorus in this hay as compared with the mixed hay is just about half as much per pound of dry matter.

TABLE 5. *Phosphorus fractions on the Coon Creek timothy samples,* 1927.

		Phosphorus fractions P_2O_5 (per cent).							
Sample No.	Pounds of phosphate fertilizer applied	Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
11	None.	.28	.17	.12	59.2	41.8	.16	.05	.12
12	None.	.27	.16	.11	60.7	41.2	.16	.05	.10
15	None.	.24	.15	.08	61.9	33.6	.16	.07	.09
16	None.	.22	.15	.09	67.1	38.3	.14	.06	.07
17	None.	.27	.22	.14	82.0	52.6	.13	.08	.05
13	200 lbs.	.44	.33	.28	75.5	64.0	.16	.05	.11
14	1500 lbs.	.53	.37	.32	70.5	61.5	.20	.05	.16

The alsike fraction of the mixed hay gives an increase of 175 per cent in total P_2O_5 as shown in table 6, and the increase in the inorganic fraction ranges from 30 per cent of the total P_2O_5 in the check plot to 60 per cent under high fertilizer treatment. Here again, as in the timothy, there is an increase noticeable in the organic fraction under the 1,500 pound per acre application of fertilizer. The value of 0.43 for percentage of organic phosphorus in the alsike clover under the 1,500 pound treatment of fertilizer cut in July, 1927, is very close to the value for the same fraction throughout the mixed hay samples cut in the fall of 1926.

The alfalfa samples from the upland plots at the Coon Creek Experiment Station were collected May 31st, 1927. These samples show a 34 per cent increase in total phosphorus in the treated plots as compared with the check plot, see table 7, and an increase of 48 to 62 per cent of the total P_2O_5 in the

inorganic fraction, the organic fraction showing very little change throughout the series.

Table 6. *Phosphorus fractions on alsike clover from the Coon Creek peat plots,* 1927.

Sample No.	Pounds of phosphate fertilizer applied	Phosphorus fractions P_2O_5 (per cent). Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
11	None.	.40	.24	.13	61.4	33.6	.26	.11	.15
12	None.	.41	.21	.12	52.1	30.0	.29	.09	.19
15	None.	.46	.33	.20	71.0	43.5	.26	.13	.13
16	None.	.44	.24	.14	55.2	32.1	.30	.10	.20
17	None.	.50	.33	.20	66.0	41.1	.29	.12	.17
13	200 lbs.	.56	.37	.29	66.6	51.2	.27	.09	.19
14	1500 lbs.	1.11	.90	.67	81.5	60.8	.43	.23	.21

Table 7. *Phosphorus fraction of alfalfa from the Coon Creek upland plots,* 1927.

Sample No.	Pounds of phosphate fertilizer applied	Phosphorus fractions P_2O_5 (per cent). Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
18	None.	.83	.47	.40	56.5	48.1	.43	.07	.36
20	100 lbs.	.79	.49	.41	62.1	51.9	.38	.08	.30
19	200 lbs.	.88	.57	.45	64.3	51.4	.43	.11	.32
21	400 lbs.	.89	.65	.54	73.0	61.1	.35	.11	.24
22	600 lbs.	.98	.68	.56	68.9	56.5	.43	.12	.31
23	1000 lbs.	.99	.67	.55	67.5	55.1	.45	.12	.32
24	1500 lbs.	1.01	.74	.63	73.5	62.5	.38	.11	.27
25	2000 lbs.	1.11	.81	.68	73.4	61.0	.43	.14	.30

The data listed in table 8 from a series of rape samples grown for 8 weeks on Coon Creek peat as pot experiments, show an increase of 130 per cent in total P_2O_5, the inorganic fraction increasing from 45.0 per cent total P_2O_5 on the checks to 69.0 per cent on the heavy treated plots; here again the organic fraction shows a slight increase over the check plot, but slightly lower than the plot with the 100 pound per acre application of fertilizer, so that it can be said that the high application of fertilizer in this case does not increase the organic phosphorus fraction to any appreciable extent.

The data on the mature rape plants, table 9, indicate a tremendous increase in total P_2O_5; practically 300 per cent. The inorganic increases from 63.0 per cent on the check plot to 83.0 per cent on the fertilized plots, higher than any of the previous crops. In this series again the higher fertilizer applications seem to give a certain increase in the organic fraction, but the increase is slight compared to the P_2O_5 present, while the 500 pound per acre application of fertilizer gives a higher organic fraction than the 2,000 pound treatment.

Another series of rape samples, table 10, grown on Alberta peat soil pot experiment for a period of 8 weeks, gives very similar results to the series on Minnesota peat, table 8.

TABLE 8. *Phosphorus fractions on an early cutting of rape,* 1927.

Sample No.	Pounds of phosphate fertilizer applied	Phosphorus fractions P_2O_5 (per cent). Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
26	Check	.51	.32	.23	62.8	44.9	.28	.09	.19
27	100 lbs.	.87	.65	.49	74.5	56.3	.38	.16	.22
28	200 lbs.	1.00	.83	.62	83.0	62.1	.38	.21	.17
29	500 lbs.	1.08	.86	.72	79.9	66.2	.27	.15	.22
30	1000 lbs.	1.15	.97	.82	84.5	71.2	.33	.15	.18
31	2000 lbs.	1.18	1.01	.81	85.5	68.4	.37	.20	.17

TABLE 9. *Phosphorus fractions on a series of matured Rape samples,* 1927.

Sample No.	Pounds of phosphate fertilizer applied	Phosphorus fractions P_2O_5 (per cent). Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
32	none.	.50	.37	.32	73.0	62.9	.19	.05	.14
33	100 lbs.	.79	.66	.55	83.5	69.2	.24	.11	.13
34	200 lbs.	.99	.89	.81	89.1	81.4	.19	.08	.11
35	500 lbs.	1.52	1.34	1.13	88.4	74.4	.39	.21	.18
36	1000 lbs.	1.98	1.82	1.64	91.8	81.8	.34	.18	.16
37	2000 lbs.	1.97	1.75	1.63	88.8	82.7	.34	.12	.22

TABLE 10. *Phosphorus fractions on some early cuttings of Rape, Alberta,* 1928.

Sample No.	Pounds of phosphate fertilizer applied	Phosphorus fractions P_2O_5 (per cent). Total	Total Inorganic	Inorganic as per cent of total	Total organic
53	None.	.64	.29	44.3	.36
54	100 lbs.	.80	.40	50.5	.40
55	250 lbs.	.98	.52	53.5	.46
56	750 lbs.	1.06	.57	53.2	.49
57	1000 lbs.	1.20	.76	63.0	.54
58	2000 lbs.	1.24	.96	77.0	.28

A number of native hays were collected from different parts of the country, four from Alberta, and one from Minnesota. These were analyzed with a view to determining the variation, if any, that may occur in hays under different soil and climatic conditions. The hays have a low content of total phosphorus as shown in table 11, about 50 per cent of which is organic.

The samples from a series of wheat, sweet clover and barley experiments carried out in Alberta on podsolic or bush land soils under lime and phosphorus applications were analyzed (see table 12). These experiments were carried on to study the effect of lime and phosphorus on the above crops, as these soils in general respond to this treatment. The samples were supplied by the Soils Department, University of Alberta, for this work. The sweet clover, barley straw and wheat straw, show decided increase in inorganic phosphorus. The straws give a higher inorganic phosphorus fraction than the legume. The organic fraction seems to increase in the case of the wheat

straw and clover but not in the barley. The increase of total P_2O_5 in all cases averages around 100 per cent for the treated plants. The grains from the same plots show very little variation of the treated over the untreated; in all fractions, however, the organic fraction is by far the larger portion of the phosphorus.

The results in table 13 show the phosphorus fractions on a number of Minnesota native upland hays, slough hays, and cultivated alfalfa and timothy. The hays were collected in connection with the study of mineral deficiency in feeds and the condition of cattle as noted in the districts from which the hay was obtained, is given in the table. These hays on the whole are low in phosphorus, even the alfalfa samples, but there does not seem to be any correlation between the individual fractions such as inorganic as shown in this table, and the report of the condition among the stock.

TABLE 11. *Phosphorus fractions on Alberta native hays.*

		Phosphorus fractions P_2O_5 (per cent).							
Sample No.	Description or treatment	Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
38	A Minnesota prairie hay.	.13	.10	.07	73.3	49.6	.07	.03	.03
39	Alberta bush soil upland hay.	.33	.26	.22	78.9	67.5	.10	.04	.07
40	Peat hay in bush country.	.15	.13	.05	82.8	35.1	.10	.07	.03
41	Dry plains prairie hay.	.18	.13	.08	69.9	44.2	.10	.05	.05
42	Plains hay (transition)	.20	.20	.10	98.0	50.3	.10	.09	.01

TABLE 12. *Phosphorus fractions on a series of sweet clover, wheat, and barley.*

		Phosphorus fractions P_2O_5 (per cent).							
Sample No.	Description or treatment	Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic	Soluble organic	Insoluble organic
43	Sweet clover (check)	.28	.16	.11	56.7	37.6	.18	.05	.12
44	Sweet clover (Ca + P)	.66	.50	.39	75.4	59.4	.27	.11	.16
45	Wheat straw (check)	.22	.20	.18	88.0	79.0	.05	.02	.03
46	Wheat straw (Ca + P)	.56	.51	.49	91.5	88.4	.06	.02	.05
47	Barley straw (check)	.44	.39	.31	89.6	71.5	.12	.08	.05
48	Barley straw (Ca + P)	.89	.83	.78	93.8	87.5	.11	.05	.06
49	Wheat grain (check)	1.18	1.02	.08	86.2	6.7	1.10	.94	.16
50	Wheat grain (Ca + P)	1.17	1.04	.14	89.0	12.1	1.03	.90	.13
51	Barley grain (check)	1.31	.66	.15	50.6	11.5	1.26	.51	.65
52	Barley grain (Ca + P)	1.30	.69	.07	52.8	5.16	1.23	.62	.62

TABLE 13. *Phosphorus fractions on some Minnesota native hays.*

Sample No.	Kind of hay	Condition of cattle in area	Phosphorus fractions P_2O_5 (per cent). Total	Total Extract	Total Inorganic	Extract as per cent of total	Inorganic as per cent of total	Total organic
1014a	Alfalfa (Timber Soil)	Good	.70	.50	.41	72.0	58.0	.29
1006a	Alfalfa (Prairie Soil)	Bad	.41	.38	.23	91.6	57.2	.18
1013a	Alfalfa (Timber Soil)	Bad	.52	.39	.32	75.4	60.5	.21
1003a	Alfalfa (Prairie Soil)	Bad	.59	.33	.13	54.9	22.2	.46
1007a	Alfalfa (Timber Soil)	Bad previously	.46	.32	.27	68.5	57.5	.20
1007b	Alfalfa (Timber Soil)	Bad previously	.46	.32	.26	69.4	56.0	.20
1034a	Alfalfa (Prairie Soil)	Bad	.41	.23	.20	56.5	48.0	.21
1001a	Alfalfa (Prairie Soil)	Bad	.42	.23	.18	54.7	44.8	.23
1017	Alfalfa (Prairie Soil)	Bad	.28	.15	.09	51.0	32.1	.19
1020	Alfalfa (Timber Soil)	Slight trouble	.48		.29		60.5	.19
1013b	Alfalfa	Good	.46		.22		48.2	.24
1029a	Alfalfa, (Clay soil)	Fairly good	.35	.21	.13	59.3	37.8	.22
1029b	Wild hay	Bad	.40	.31	.22	76.9	54.5	.18
1001b	Wild hay, Prairie	Bad	.31	.23	.20	74.0	62.8	.12
1008	Wild hay, Prairie	Bad	.22	.16	.11	70.3	49.5	.11
1022b	Wild hay, Timber	Good	.24	.15	.09	63.8	39.1	.15
1018b	Wild hay, Prairie	Bad	.17	.13	.07	76.5	39.8	.11
1002	Wild hay, Prairie	Good	.26		.13		48.5	.13
1010	Wild hay, Prairie	Bad	.22	.14	.09	64.5	43.5	.13
1018c	Wild hay, Prairie Slough	Bad	.26	.17	.14	63.2	52.3	.13
1009	Wild hay, Prairie	Bad	.14		.07		51.8	.07
1033a	Wild hay, Prairie	Bad	.19	.11	.06	57.8	33.2	.13
1026	Wild hay, Prairie	Slight trouble	.13	.06	.04	48.0	27.1	.09
1028	Wild hay, Lake Bed	Slight trouble	.18		.13		71.2	.05
1025	Wild hay, Near Marsh	Bad	.18	.09	.05	47.8	23.4	.14
1032a	Wild hay, Prairie	Bad	.15	.04	.03	27.5	20.9	.12
1027	Wild hay, Lake Bed	Good	.16	.08	.04	51.5	27.0	.12
1016	Wild hay, Timber	Good	.15	.09	.06	55.2	35.7	.10

In the unfertilized hays the percentage of organic is generally higher than in the fertilized plots because of the increase in the inorganic fraction under fertilization. Legumes seem to be higher in organic P_2O_5 than prairie hays but they are also higher in total P_2O_5.

DISCUSSION

Graphical representation of data

The relationship of the three fractions, total, inorganic and organic phosphorus, is shown in figures 1, 2, and 3.

In all crops except the alsike clover and fall or late cutting of rape, figure 1, the total phosphorus of the hays shows a very rapid increase up to about a 200 pound application per acre of phosphorus fertilizer; from this point there is a continued gradual increase. The rape late cutting shows a similar curve but the increase continues to rise rapidly until 1000 pounds of fertilizer have been applied, and at this point the maximum seems to have been obtained. The alsike hay might show a somewhat different curve if a few more values had been plotted between the 200 pound application of phosphate and the 1500.

The curves for inorganic phosphorus, figure 2, are similar to those in figure 1, resembling the increase for total phosphorus very closely except the Alberta rape. This curve seems to show a general increase in inorganic throughout. Alsike has the same type of increase here as shown in total phosphorus.

In figure 3 quite a different set of curves is found for the organic fraction of phosphorus. Timothy, alsike, alfalfa, and the mixed hay samples show a decrease in total organic with the lower applications of phosphorus fertilizer as compared to the check plots, and in the higher treatments a slight increase. The three rape samples show an increase from the check plot to about the 1000 pound application and then a flattening out of the curve. The late cutting rape shows a point under the 2000 pound application that was so low in organic as to appear more or less out of line with the general trend of this fraction, so much so that the curve for this crop has not been extended to this point but was drawn only as far as the 1000 pound fertilizer application, to which point the curve follows the same trend as the other rape crops.

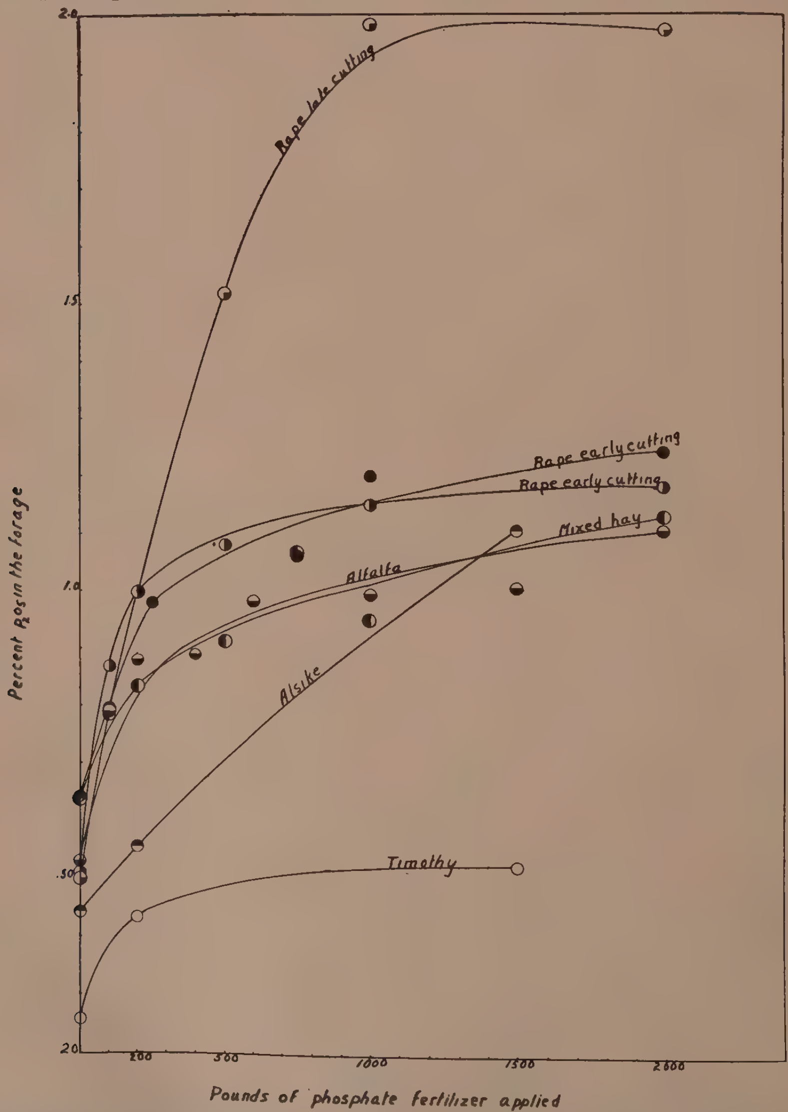

Figure 1. Showing the increase of total phosphorus in hays under increasing amounts of phosphate fertilizer in the soils.

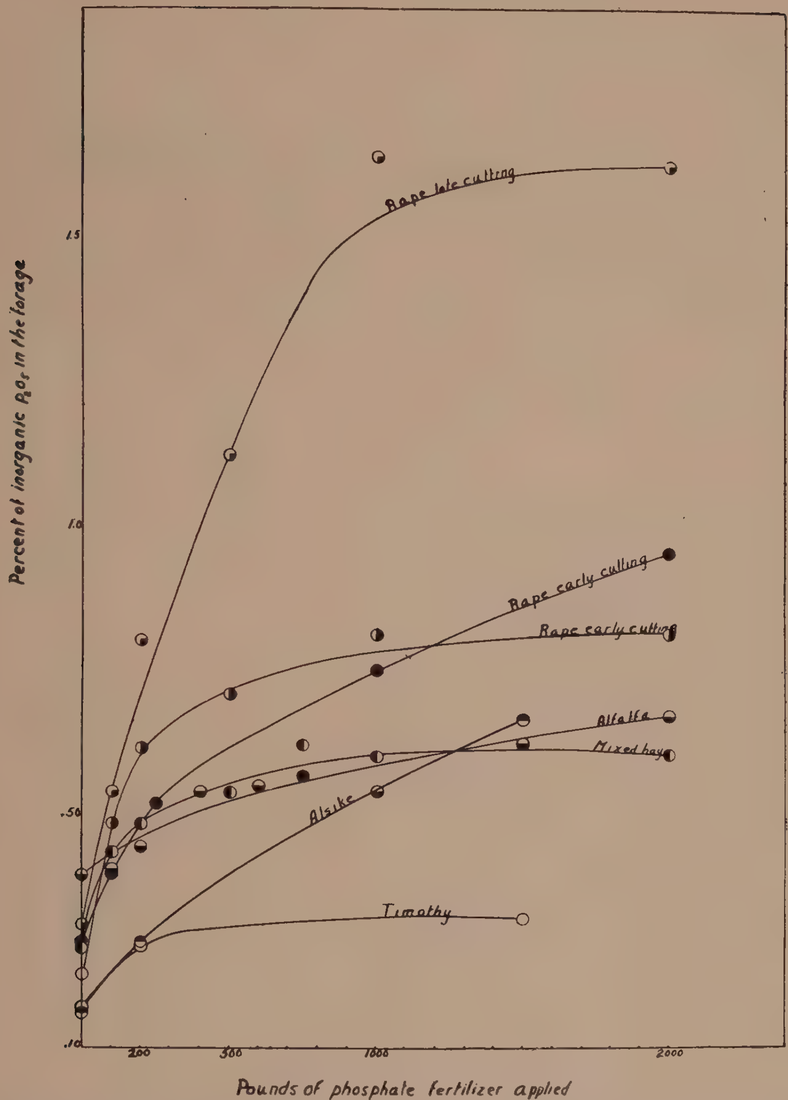

Figure 2. Showing the increase of inorganic phosphorus in hays under increasing amounts of phosphate fertilizer to the soil.

The values do not by any means fall on a smooth curve, but it is believed that the curves show quite clearly, when drawn as close as may be to the values given, the general trend of this fraction of phosphorus. The immediate increase of the organic phosphorus under the lower applications of phosphorus fertilizer seems peculiarly a characteristic of the rape samples only, while the other hays show quite a decrease at this point.

The graphs show fairly conclusively that the greater portion of the increase in phosphorus content of a hay is in the inorganic fraction. The only appreciable increase in organic phosphorus in actual pounds per acre of hay would be in the increase in pounds of hay per acre, and a maximum

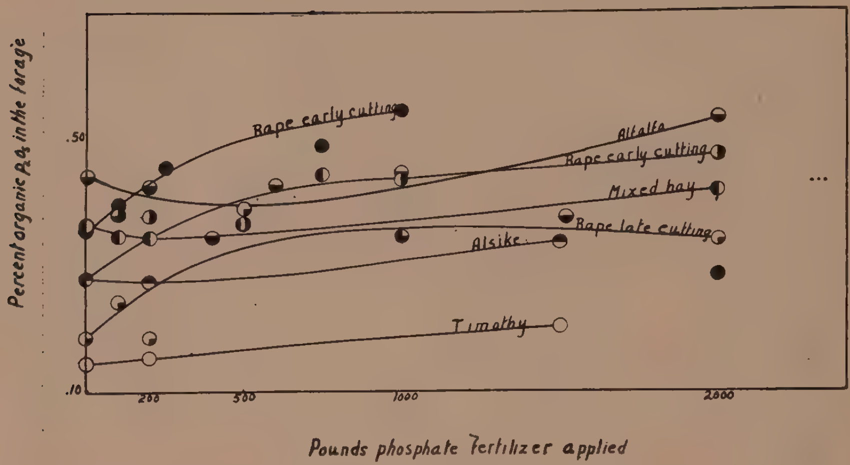

Figure 3. Showing the increase of organic phosphorus in hays under increasing amounts of phosphate fertilizer to the soil.

production of hay can readily be obtained under the 200 to 400 pound application of "Treble Superphosphate" fertilizer.

Statistical treatment of data.

In an attempt to bring out still further the points shown in the curves, the various fractions of phosphorus were correlated with the fertilizer applied, using the method of Harris (*22*), 1910.

The three rape series were combined and, in the case of the total phosphorus, correlated against fertilization r = + .974 ± .007, bringing out the close relationship between the two. Where inorganic is compared with fertilization r = + .591 ± .061, not quite as good a correlation as in the case of total, but showing a decided increase, nevertheless, with increased phosphorus to the soil. Where organic is correlated against fertilization r = + .282 ± .036, bringing out as in figure 3 the slight increase in organic. The two fractions, organic and inorganic phosphorus were compared. The values r = + .410 ± .103, indicate a certain increase in organic with increase in inorganic.

The peat hays, timothy and alsike of 1927 and the mixed hay of 1926 were compared in the same manner. Where total phosphorus of the hay is correlated with fertilizer application r = + .483 ± .163, inorganic against fertilizer r=+.591±.061, and organic against fertilizer r=+0.34±.240. These results show a much lower correlation between total phosphorus and inorganic against fertilization, with a better correlation between organic and fertilization than in the rape series, though the probable error in this latter case is large enough to make the correlation of little significance. Correlating organic against inorganic r = + .916 ± .030, a high correlation, showing a greater increase of organic per increase in inorganic than in any of the other series. The high correlation here is probably accentuated by the fact that in case of the timothy and alsike only two values apiece are available.

The alfalfa samples treated in the same manner, for total phosphorus against fertilizer r = + .932 ± .038, inorganic against fertilization

r = + .477 ± .197, organic against fertilizer r = + .001 ± .255, and inorganic compared with organic r = + .00003 ± .255. The total phosphorus shows a high correction value with fertilizer applied, the inorganic fraction due to the high probable error is of little value, but the organic fraction correlated with fertilizer and the two fractions, organic and inorganic, compared, show no correlation whatever.

General discussion of data. In general the Coon Creek crops show an increase in inorganic P_2O_5 of from 41 to 63 per cent, under increased fertilizer treatments, the organic fraction therefore decreasing from 59 to 37 per cent of the total P_2O_5. The actual amount of P_2O_5 in organic combination in these crops does not vary much, showing a slight increase in the timothy and alsike under the heavier treatments. The timothy hay is lower in total phosphorus, as are also the prairie wild hays, but the percentage of inorganic P_2O_5 of the total in the timothy crop is about the same as in the legumes.

It may be of interest in discussing these results to quote some of the earlier works on forages and compare the results with the above data. Much of the previous work done will not be discussed because of the difference in the earlier methods and the doubts expressed by Rather (*40*) and Forbes (*20*) as to the accuracy of the results from the use of these methods.

MacGillivray (*30*), in some work on tomato plants, states that there is a "re-utilization"* of phosphorus in plants, under phosphorus deficiency and the growth under such conditions is in the upper leaves, in this work confirming the work of André (*6*), who states there is greater redistribution of phosphorus in the plant than of other minerals. MacGillivray's data indicate an increase of phosphorus in the fruit towards ripening; this in turn has been found to be the case in seeds of plants.

It would appear, therefore, that the big increase in yield under the first applications of phosphorus might be due to a supply of phosphorus sufficient to carry on growth on a large leaf surface, instead of in local areas as mentioned by MacGillivray under phosphorus starvation. This being the case, the curing of a hay to prevent loss of a portion of the leaves would be quite important in harvesting.

Among forage plants, according to Forbes, leguminous hays and bluegrass are high in phosphorus, while timothy hay and wheat straw are low in this constituent. This is shown to be true when comparing the timothy of table 4 and the straws of table 12, with the legumes. He states that the content of phosphorus of all sorts of roughage is much affected by the soil. It would appear from the results of table 12 that this is much more true in case of the roughage than in the case of the grains.

Ames and Boltz (*2*) find first cuttings of alfalfa higher in total phoshporus in all cases than the second cuttings. They also state that the mineral elements are loosely combined in the forage plants and are, therefore, easily leached out by rain. They state that 0.5 inches of rain on an alfalfa crop may decrease its value 25 per cent due to leaching of inorganic constituents, and in an experiment they determine 75 per cent of the phosphorus of alfalfa

*Term used by MacGillivray to describe the translocation of phosphorus from the older tissues to the growing parts.

as soluble in distilled water, and they list 43 - 63 per cent of alfalfa phosphorus as organic, somewhat higher values than the 38 to 52 per cent found on the Coon Creek plots. They report that for every increased condition of fertilization, a greater proportion of the total phosphoric acid is present as organic phosphorus. This is not brought out in the alfalfa plots from Coon Creek. They believe alfalfa cut in the bloom to contain the largest amounts of the more valuable plant foods and nutritive constituents of the leaves.

Quite a variation in mineral constituents, including phosphorus throughout the growing season, is reported by different authors. Elliot, Orr, Wood and Cruikshank (*15*) report Leicestershire pastures as having their maximum nitrogen and phosphorus early in May, other fodders having their maximum in June. The Veld hays of South Africa as reported by Theiler (*48*), decrease steadily in phosphorus content from 0.6 per cent of P_2O_5 in November to .09 per cent in June. Crowther and Ruston (*12*) report the tendency of potassium and phosphorus to decrease as the season advances, while Fagen and Jones (*16*) found throughout the season that phosphorus rose to a maximum and then decreased. Woodman, Blunt and Stewart (*50*) report calcium in pasture rising to a maximum and then decreasing, but find phosphorus showing opposite behaviour.

From these references it may be gathered that there is a definite seasonal variation in the phosphorus content of fodders but there does not seem to be in all cases a definite trend in any one direction, though the concensus of opinion seems to favour a decrease as the season advances. In the the above tables the organic fraction of the fall cutting of mixed hay is higher than the hay cut the next year in July and the alfalfa cut on May 31, 1927 is as high in this fraction as the alsike timothy mixture cut in the fall and higher than the alsike cut in July. However, this is not a fair comparison, as the crops are different, though both legumes and the alfalfa is grown on upland while the alsike is grown on peat.

In the rape experiments the spring cutting, table 8, and the Alberta samples, table 10, may be said to show no increase of organic phosphorus under increased application of fertilizer. The fall cutting shows some increase under the higher applications but the 500 pound application gives the highest organic content so these differences may be small.

Silica content of hays. During the ashing of the hay samples for total phosphorus a difference was noticed in the insoluble ash of the timothy and legumes. A certain difference in the insoluble ash of the legumes under high and low phosphorus treatments was also observed, and some samples were analysed to determine the extent of this difference.

The hays were ashed and then treated with concentrated hydrochloric acid and the residue filtered, dried, burned and weighed.

The data on native hays show the large increase in silica on these kinds of hays as compared with the legumes or timonthy. Elliot, Orr, Wood and Godden (*14*), in their work on cultivated and uncultivated pastures, re-

TABLE 14. *Comparing the acid insoluble ash and the P_2O_5 of hays.*

Sample No.		Total P_2O_5 per cent	Acid Insol. Ash per cent.
T 17	Timothy check.	.27	3.22
T 14	Timothy, 1500 lbs. Fertilizer.	.53	2.02
A 17	Alsike check.	.50	0.40
A 14	Alsike, 1500 lbs. Fertilizer	1.11	0.31
18	Alfalfa check	.83	1.05
25	Alfalfa, 2000 lbs. Fertilizer	1.11	.50
	NATIVE HAYS		
38	Prairie hay	.13	5.66
39	Wild hay, timber	.33	8.24
42	Prairie hay	.20	8.03
41	Prairie hay	.18	7.46
49	Peat hay	.15	5.21

port the cultivated pastures as giving the hay with the highest silica free ash, the wild hays being highest in silica.

Schollenberger (*44*), in some work on silica, shows that silica is assimilated by plants when added in available form, but he states that added silica did not help the plant utilize more phosphorus from a furnace slag, while silica from calcium silicate seemed to help the utilization of phosphorus. Most of his work was carried out as pot experiments, but on a field test he states that where silica was added as a slag, the phosphorus showed a decrease, though the yield increased. He believed this to be due to the high nitrogen content of the field rather than to any effect of the added silica.

These data on the timothy, alsike and alfalfa may indicate a certain utilization of silica under phosphorus deficiency. The timothy and alsike hays are from a peat soil while the alfalfa is from a sand. As much as 100 per cent increase may be seen in the case of the alfalfa.

Crude protein nitrogen of hays. Some further work was carried out on the alfalfa, alsike and timothy samples to study the effect of the fertilizer treatment on nitrogen metabolism. A number of samples were selected representing low and high phosphorus treatment of these hays.

MacGillivray's (*30*) work with tomato plants seems to indicate some relationship between the phosphorus and nitrogen of these plants. He states that plants in nutrient solutions under starved conditions respond much quicker to nitrogen fertilization than to phosphorus. Apparently a plant deficient in nitrogen can take up nitrogen from the solution at different stages of its growth and utilize it immediately, while it cannot utilize phosphorus quite so readily, if under phosphorus deficiency treatment and phosphate fertilizer is applied.

He concludes that nitrogen and phosphorus deficiency show certain points in common, such as stiffening of the stems, decrease of chlorophyll, appearance of anthocyanin pigments on the under side of the leaves; his results show embryonic regions, which are high in protein content, such as fruit clusters, stems, the tops of the leaves, and the tops of stems, to be high in both phosphorus and nitrogen.

Plants grown in sand in the absence of phosphorus show a greater percentage of nitrogen than plants having an ample supply of phosphorus. His plants grown in the absence of phosphorus show a decrease in the percentage total nitrogen and also the total amount of coagulable nitrogen, as compared with the coagulable nitrogen of plants grown under sufficient phosphorus treatment. Ames and Boltz (*2*) state in connection with their alfalfa experiment that 80 per cent of the protein of the plant is present in the leaves, the percentage of nitrogen, as well as phosphorus, is found highest in the first cutting of alfalfa, and more total nitrogen is combined as protein in the second cutting than in the first, 66 per cent in the first cutting and 77 per cent in the second being found as protein nitrogen. It would therefore appear that the nitrogen varies in much the same order as the phosphorus.

TABLE 15. *Table showing comparison of crude protein and phosphorus content of hays.*

Sample No.	Treatment	Per cent P_2O_5	Per cent crude Protein
Timothy 11	No treatment	.28	8.92
Timothy 12	No treatment	.27	8.83
Timothy 17	No treatment	.27	8.45
Timothy 14	1500 lbs. phos.	.53	7.88
Alsike 11	No treatment	.40	15.75
Alsike 12	No treatment	.41	15.22
Alsike 17	No treatment	.50	15.69
Alsike 13	200 lbs. phos.	.56	16.04
Alsike 14	1500 lbs. phos.	1.11	17.86
Alfalfa 18	No treatment	.83	28.20
Alfalfa 25	2000 lbs. phos.	1.11	28.69
Mixed hay 1	No treatment	.67	25.33
Mixed hay 2	No treatment	.61	25.78
Mixed hay 7	2000 lbs. phos.	1.13	23.44

The literature cited on this phase of the problem seems to show a relationship in practically all cases between the nitrogen and the phosphorus.

The above data on nitrogen of the Coon Creek hays show a decrease of crude protein in the high phosphorus timothy samples as compared with the checks. In the alsike grown on the same plots as the timothy the same year the crude protein shows an increase of about 14 per cent. The mixed hay timothy and alsike cut in the fall of 1926 shows a higher crude protein content throughout than the early cutting of alsike and timothy 1927, but the fertilized plots show a decrease in nitrogen as compared with the checks. The alfalfa crop is very similar in nitrogen content on check plots and under 2000 pounds phosphate fertilization.

In general these data show no general trend of the crude protein nitrogen fraction, certainly no direct relationship to the fluctuations in the phosphorus throughout the three groups.

SUMMARY

Various methods for the determination of inorganic phosphorus in the presence of organic phosphorus in plant tissues were compared, with a view to obtaining a rapid and accurate method for this type of analysis. A modification of the Fiske and Subbarow colorimetric method for phosphorus was

developed, which proved much more rapid than any of the older volumetric methods, and proved more accurate, due to the prevention of hydrolysis of organic phosphorus compounds which may occur in the more time-consuming methods.

This modified method proved accurate and rapid in the determination of total phosphorus in plant tissues, and with a few alterations proved very satisfactory as a method for the determination of total soil phosphorus.

Many samples of forage crops were examined to determine the extent to which total phosphorus increased in the plant tissues under various applications of phosphate fertilizer, and to what extent this increase, if any, occurred in the inorganic or the organic fractions. Very large increases in total phosphorus in plants were obtained on the plots receiving heavy fertilizer applications as compared to the check plots receiving no fertilizer. The increases in phosphorus found in the various crops expressed as per cents, were respectively: a mixed hay (alsike clover and timothy) cut in October, 69; timothy from the same plots cut in July, 89; alsike, 175; alfalfa samples from upland sandy soils, 34; two sets of rape samples cut at the end of six weeks growth, 130 and 94; sweet clover, 135; wheat straw, 150; barley straw, 100. An average of the various increases in the above crops gave 100 per cent increases, or a doubling of the phosphorus content, due to the application of fertilizer.

A sample of rape allowed to mature, gave a 300 per cent increase in total phosphorus. This value was not included in the above list as being above the average increase.

Practically the entire increase in total phosphorus of hays was confined to the inorganic phosphorus fraction, fertilization increasing the organic fraction only in so far as it increased the pounds of hay per acre.

Very heavy fertilizer applications were necessary to obtain these large increases of inorganic phosphorus in the plant. The fertilizer experiments show, on the other hand, that a maximum yield in pounds of hay per acre can be obtained with a 200 pound application of treble superphosphate, instead of the 1000 to 2000 pound applications necessary to give the extremely high phosphorus content obtained in these crops. It would seem, therefore, that phosphate fertilizer could be profitably applied only in so far as it increased the pounds of hay per acre, and that phosphate required in a ration in excess of the quantity supplied in such a hay could be added directly to the feed.

Where it was deemed necessary to supplement a ration with organic phosphorus, this could be done by feeding cereal grains rather than by attempting to increase the organic phosphorus content of forage crops by means of large applications of phosphate fertilizer. These grains contain high percentages of phosphorus, for the most part in organic combination, and they do not show the extreme fluctuations in percentage phosphorus which seem characteristic of forage plants.

The content of silica in the ash of the various hays appears to decrease with the application of fertilizer. The variation, in the case of alfalfa,

between the check plots and those receiving fertilizer was 100 per cent. The legumes in general from the check plots, did not exceed 1.0 per cent of silica, with decidedly less on the fertilized plots. Timothy contained 2.0 to 3.0 per cent of silica under all treatments, showing the largest percentages, however, on the check plots, while the native wild hays contained as high as 5.0 to 8.0 per cent.

Alsike showed an increase in protein under the higher phosphorus application, timothy and mixed hay a decrease, while alfalfa showed very little difference between the high and low phosphorus plots. In general no direct relationship was shown in the fluctuations of nitrogen and phosphorus in the series of samples worked with.

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LE PROBLEME HORTICOLE DANS LA PROVINCE DE QUEBEC*

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A. Apercu General

Si rapides et considérables furent les progrès faits dans les sciences, depuis le commencement du XIXème siècle, qu'ils ont occasionné des bouleversements sociaux et économiques qui ont profondément modifié les conditions d'existence de l'humanité.

Les étonnantes découvertes de la chimie, de la physique et de la physiologie, la prodigieuse utilisation de l'électricité, l'extraordinaire extension des moyens de transport et de communication et le merveilleux développement du machinisme, ont fait surgir un monde industriel basé sur la concentration de toutes les forces vives de la production; un monde social édifié sur des besoins nouveaux, sur le groupement des individus, des classes et des sociétés; un monde économique dont l'équilibre repose sur l'étroite solidarité de l'agriculture et de l'industrie.

Entraînée par cet impétueux courant d'évolution des activités humaines que ébranla les assises du vieux monde sur lesquelles elle reposait, l'agriculture mondiale, jusque-là indépendante parce qu'elle était la seule spéculation des peuples civilisés, devient partie intégrante du mécanisme constituant le nouveau monde économique.

Désormais, la régularité du mouvement économique qui engendre le bien-être et la richesse des nations, résultera de la pondération ou de l'harmonieux équilibre de leurs forces productrices, c'est-à-dire du développement proportionnel et simultané de leurs diverses industries, l'agriculture jouant, en l'occurrence, le rôle décisif d'industrie de base. Car, "la richesse d'un peuple", disait M. Méline, "est comparable à un arbre: l'agriculture en "est les racines; l'industrie et le commerce, les branches et les feuilles. Si "les racines viennent à souffrir, les feuilles tombent, les branches se brisent, "se détachent et l'arbre meurt. Tant que les racines sont vigoureuses, la "feuille malade ou la branche blessée se rétablissent et l'arbre vit."

Puisqu'en évoluant sous l'influence des progrès de la technique dans tous les domaines, l'agriculture a perdu son indépendance d'autrefois, pour devenir "une industrie comme une autre", c'en est donc fini de l'agriculture de clocher, de l'isolement et de la routine de l'agriculteur. Universalisées par la rapidité et l'économie des transports, les productions agricoles n'ont maintenant plus de nationalité. Aussi l'agriculteur, stimulé par l'aiguillon de la concurrence, ne peut-il trouver, aujourd'hui, que dans la force collective de l'association, l'unique remède à son isolement et le seul moyen efficace de lutter—non plus comme autrefois, contre ses concurrents voisins seulement, mais bien contre ceux de l'univers entier. D'empirique et de routinière qu'elle était, l'agriculture s'étant élevée au rang de science, ce n'est que par le recours à l'instruction agricole que le travailleur du sol pourra décupler

*Extraits d'une conférence prononcée à Québec le 5 mars, 1929.

son action, raisonner ses cultures et augmenter ses rendements. Mais l'appétition naturelle vers le bien-être étant de nos jours, plus que jamais, le mobile de l'activité humaine, l'ouvrier des champs ne consacrera ses bras et son intelligence à l'agriculture que si elle le rétribue suffisamment pour qu'il n'ait rien à envier au confort de l'ouvrier des villes.

En d'autres termes, l'agriculture ne saurait évoluer progressivement dans aucun pays, à moins d'y être assez payante pour garder les bras dont elle a besoin. Ne pouvant être lucrative qu'à la condition d'avoir des débouchés, et le marché intérieur étant le débouché par excellence de l'industrie nationale, il importe donc, au plus haut point, de prendre les moyens de le lui assurer, en développant simultanément la production de pair avec l'industrie et le commerce qui accroissent le nombre des consommateurs et en multipliant les modes de transport et de communication qui facilitent les rapports entre producteurs et consommateurs.

Or, parmi les causes très nombreuses qui entravent ce développement proportionnel et simultané des diverses industries, déterminant ainsi l'instabilité du milieu économique qui est le noeud de la question agricole, signalons les suivantes:

1o.—l'insuffisance des capitaux investis dans l'exploitation et l'industrialisation agricoles, qui influe considérablement sur la condition matérielle de l'homme des champs, en paralysant sa puissance productrice. La production agricole étant exposée à beaucoup de risques et son amélioration, toujours coûteuse, ne donnant que des résultats tardifs, il devient conséquemment difficile d'entraîner les capitaux vers une entreprise aussi aléatoire. Nonobstant cette difficulté, l'agriculture pourrait se pourvoir elle-même d'une bonne partie des capitaux qui lui sont nécessaires, si elle n'était pas saignée à blanc par le drainage de l'épargne rurale vers les plus hasardeuses spéculations industrielles et commerciales. Cette tendance au suicide agricole semble être à ce point générale que l'on croirait que M. Chabrun, député français, ait voulu parler de ce qui se passe chez nous, lorsqu'il écrivait: "Qui dira ce que l'on pourrait tirer de l'épargne agricole habilement utilisée par les agriculteurs et pour l'agriculture? Aujourd'hui, cette puissance disséminée appartient à qui veut la prendre, c'est-à-dire, surtout, aux démarcheurs habiles qui alimentent, par l'argent du bas de laine des paysans, les affaires les plus étranges et il arrive que cette énergie, venue de la terre, est souvent employée contre les intérêts mêmes des travailleurs du sol."

2o.—le trop peu d'importance que les pouvoirs publics attachent généralement à l'agriculture de même que le dédain que les consommateurs affichent pour l'agriculteur et son art et qui affectent profondément sa situation morale, en le mettant sous la déprimante impression qu'il est le paria de la société.

Et pourtant, l'agriculture n'est-elle pas comme le disait Fénélon, "le fondement de la vie humaine, la source "de tous les vrais biens?"

Etant essentiellement créatrice et produisant de toutes pièces les matières premières nécessaires à la subsistance de l'humanité, ne mérite-t-elle pas d'être plus encouragée dans son développement, mieux protégée dans ses intérêts, que les autres industries transformatrices qui n'en sont que le complément?

S'il est vrai que la terre est l'école éternelle des vertus domestiques, de l'indépendance et de la liberté, la source des forces vives d'une nation, qu'elle exerce une influence moralisatrice et une action dépurative sur l'hygiène sociale des peuples, n'est-il pas impérieusement urgent, à une époque où la civilisation est enfiévrée de lucre et infectée du virus révolutionnaire, que les classes dirigéantes se préoccupent avant tout de sauvegarder la situation morale de l'agriculteur et de lui faire aimer la terre jusqu'au culte? "Plus que jamais, dit M. Chéron, l'emblème de la civilisation, c'est la charrue!"

3o—le défaut d'instruction et d'éducation professionnelles agricoles qui tient l'agriculteur dans l'impuissance d'exploiter rationnellement son sol et d'en obtenir de hauts rendements, diminue la productivité de son travail, le maintient dans l'isolement, lui fait éprouver du dégoût pour son métier et le conduit souvent au découragement et à l'absentisme.

On a dit, avec beaucoup de justesse, que les crises agricoles ont leurs racines dans l'ignorance et l'isolement. C'est que l'art agricole est devenu tellement complexe, par suite des progrès incessants des découvertes scientifiques, qu'il exige de l'agriculteur beaucoup de connaissances, d'esprit d'observation et de raisonnement, pour adapter leurs résultats aux exigences de son milieu.

De nos jours, l'agriculteur doit non seulement savoir produire, mais encore savoir vendre, c'est-à-dire connaître les marchés, trier, classifier, emballer et expédier ses produits, conformément à leurs exigences, au temps le plus propice pour y satisfaire. Son métier est donc celui qui nécessite le plus de science et d'expérience, le plus de persévérance et aussi le plus de coopération professionnelle.

C'est un sujet d'étonnement de constater qu'à une époque où l'idée de groupement domine la société au point d'engendrer des gouvernements de classe, les cultivateurs soient si lents à s'unir et à combiner leur force collective, en vue de réduire leurs frais de production, d'abaisser leur coût de revient, de concentrer, d'uniformiser, d'intensifier, d'améliorer leurs cultures et d'organiser la vente de leurs produits.

Puisque d'après le marquis de Vogüe, "la force collective de l'association est en proportion de la force individuelle des éléments qui la composent," il s'ensuit que l'individualism déconcertant des agriculteurs provient surtout de leur défaut d'instruction et d'éducation professionnelles et que seule l'instruction—à condition d'être bien adaptée aux besoins et aux exigences de la vie rurale—pourra en avoir raison. Les pouvoirs publics ne sauraient donc trop provoquer, encourager et diffuser l'enseignement de l'agriculture qui est aujourd'hui, plus que toute autre science, disons-le avec Taine: "La science, reine impérissable du monde et de l'avenir!"

4o—la baisse des prix occasionnée soit par la surproduction, la concurrence, et surtout par la dépréciation des métaux monétaires qui occasionnent l'avilissement des prix.

La surproduction ne peut être que momentanée et non pas définitive, parce que la production cesse avec la demande. D'ailleurs, l'abondance des produits, qui est le premier élément de prospérité d'un pays, entraîne un excédent de consommation. Aussi la surproduction n'est-elle à craindre

que dans les pays qui, ne possédant pas d'information statistique précise et régulière sur l'offre et la demande de leurs produits indigènes, ne sont pas en état de s'assurer des débouchés extérieurs stables.

Beaucoup plus redoutable est la concurrence entre pays et surtout entre provinces, parce que les taux de transport, s'abaissant en raison des distances, rendent les marchés accessibles aux produits venant des points les plus éloigné. Il s'ensuit donc une lutte sur le terrain économique, et dans laquelle entrent en ligne de compte tous les facteurs de la production. Aussi, l'avantage reste-t-il à ceux des agriculteurs organisées pour produire la meilleure qualité possible au plus bas prix de revient, toutes choses égales d'ailleurs.

C'est en vain que l'on tentera de barricader les frontières d'un pays de barrières douanières, si les producteurs, ne se préoccupant pas de recourir aux mêmes moyens que leurs concurrents pour abaisser leur coût de revient et améliorer la qualité de leurs produits, veulent ainsi forcer les consommateurs à les acheter. Car autant il est nécessaire et équitable de protéger une culture ou une industrie naissante et qui—à l'instar d'un enfant—fait ses premiers pas, autant il est inutile et injuste de vouloir la protéger lorsque, devenue adulte et en état de lutter, elle manifeste plutôt des tendances au parasitisme. Dans de telles conditions, "le droit de douane, dit M. Levasseur sert à assurer "le maintien d'une partie de la rente à un instrument qui ne vaut plus ce "qu'on le loue."

Autrement plus complexe et incontrôlable est le mécanisme des répercussions monétaires. Aussi ne ferons-nous que signaler la relation intime des questions monétaires et agricoles, en citant M. Zolla qui dit que: "le "prix des produits agricoles s'est toujours élevé quand la production des "métaux précieux a augmenté, et les cours ont fléchi lorsque cette production "métallique a diminué ou est restée stationnaire." Ajoutons que la dépréciation monétaire constitue, en outre, dans certains cas, une prime à l'importation en même temps qu'une prohibition à l'exportation des produits agricoles, ainsi qu'on a pu le constater depuis la fin de la guerre.

Ce serait développer un lieu commun que d'insister ici sur l'importance d'autres causes qui ont parfois des conséquences désastreuses pour l'agriculture, telles que les maladies, les insectes nuisibles, les conditions climatériques défavorables aux récoltes, les falsifications des produits, le trop grand nombre d'intermédiaires, le manque d'éducation du goût des consommateurs, la dette hypothécaire, etc.

Cet aperçu général ne fait que soulever un coin du voile derrière lequel entrent en scène les causes et les circonstances d'ordre technique, social et économique qui gouvernent la production agricole, et qui jouent, chez nous, un rôle d'autant plus grand que notre pays est immense, sa densité démographique, faible, et son agriculture, jeune.

En effet, l'agriculture québecoise, après avoir lutté pendant près de trois siècles contre la forêt, pour y faire les larges trouées nécessaires à son extension, est à peine sortie de sa phase d'établissement que déja elle doit lutter de nouveau pour s'affranchir à la fois de la tutelle de l'industrie forestière et de la concurrence étrangère.

Ici, la terre, dépouillée de bois, ne fait plus vivre son monde, parce que s'est le bois qui, depuis plus d'un demi-siècle, faisait vivre la terre.

Là, le sol dépourvu de ses matières fertillisantes ne peut plus nourrir assez de bestiaux pour en rendre l'exploitation payante, et trop peu de bétail ne

suffit pas à nourrir le sol pour en retirer des rendements rémunérateurs.

Pendant qu'un grand nombre de domaines vieux cultivés sont à vendre ou abandonnés par leurs occupants, aux portes de Québec et Montréal, parce que leur culture ne paie plus, de nouveaux domaines sont défrichés sans relâche, aux limites les plus reculées de la province, tout comme si les mêmes causes ne devaient pas produire les mêmes effets.

Au moment où nos agriculteurs, inquiétés par la mévente de leurs produits, accusent l'agriculture québecoise de n'être plus une industrie payante pour eux, nos marchés convoités par les producteurs les plus éloignés du Canada et des Etats-Unis, regorgent de leurs denrées alimentaires qui priment par leur qualité.

Et c'est ainsi que nous assistons tous, comme acteurs ou spectateurs, à un tournant de la vie nationale dont personne ne peut prévoir les conséquences, parce que les causes sont encore loin d'avoir épuisé leurs effets. D'aucuns prétendent que c'est une crise que nous traversons. "Si c'est une "crise, dit M. Levasseur, c'est une souffrance passagère que des remèdes "temporairement appliqués pourraient soulager. Si c'est une transformation, "c'est un état définitif auquel il convient de s'accommoder tout de suite ou "par degrés." Avec lui, "nous sommes de ceux qui sont convaincus que "c'est une transformation."

Cette conviction repose sur le fait indéniable que l'agriculture n'ayant pas évolué chez nous aussi rapidement que celle de nos concurrents, doit aujourd'hui reprendre le temps et les marchés qu'elle a perdus. Elle n'y parviendra que dans la mesure où les forces publiques se combineront aux forces privées pour remédier aux causes précédemment énumérées qui entravent le développement proportionnel et simultané des diverses industries.

Ces données générales etant rappelées, passons maintenant à l'examen détaillé des conditions dans lesquelles se trouve l'horticulture québecoise qui forme une quantité nullement négligeable de la richesse nationale, puisque les progrès de l'agriculture sont étroitement liés à son développement.

B. L'Horticulture Quebecoise:

I.—*Ce qu'elle est.*

Le degré d'avancement de l'horticulture d'un pays se mesure au nombre et à la qualité de ses productions, à l'importance de son commerce et à la valeur de ses créations.

La diversité de sa production ou le nombre de ses espèces et variétés est surtout déterminé par les conditions climatériques. Sa qualité dépend à la fois du climat, du sol et de l'efficacité des méthodes et des soins culturaux: son importance commerciale se manifeste principalement par le volume de sa production, la demande dont elle est l'objet, les activités et les industries qu'elle engendre; enfin, la valeur de ses créations provient de la puissance créatrice de ses horticulteurs.

Si la rigueur de notre climat et la courte durée de végétation qu'elle occasionne ne nous permettent pas de cultiver avec succès autant d'espèces fruitières et ornementales qu'en Ontario et en Colombie-Britannique, elles nous procurent, par contre, l'immense avantage de produire un nombre assez imposant d'espèces et de variétés de produits fort recherchés, à cause de leur couleur, de leur texture, de leur saveur et de leur arome caractéristiques.

En effet, la position géographique de plusieurs de nos territoires agricoles correspondant avec l'extrême limite culturale nord, nous permet non seulement de bénéficier d'une rapidité de végétation qui donne aux fruits et aux légumes une chair tendre et juteuse, fondante et parfumée, de même que d'une rusticité qui donne à leurs semences des qualités très appréciées dans les pays situés plus au sud, mais encore de récolter chez nous au moment où il n'y en a plus ailleurs, certains produits dont la demande est toujours constante sur les marchés, lorsqu'à l'état frais.

Enfin, puisque "rien n'est si beau que son pays," pourquoi ne pas dire que la richesse de notre flore indigène a toujours ébloui jusqu'ici l'oeil connaisseur qui l'a vue?

Nous ne sommes pas moins favorisés sous le rapport de l'aptitude culturale de nos sols dont les rendements ne sont généralement pas surpassés, nulle part ailleurs, pour peu qu'ils soient "intelligemment sollicités à produire" et dont la qualité des produits est alors supérieure, dans bien des cas, à celle des produits similaires nous venant de l'extérieur.

Le défaut de qualité de nos productions ne peut donc provenir, hors des intempéries éventuelles, que de l'emploi de mauvaises semences ou variétés, que d'un sol mal approprié ou cultivé, qu'à l'absence ou à l'inefficacité de méthodes de culture et de protection des plantes ou des modes de classification, d'emballage et de conservation des produits.

Et de fait, ce sont bien là les causes reconnues qui déprécient la qualité de la majeure partie de nos productions, quand elles ne vont pas jusqu'à leur enlever toute valeur commerciale, selon qu'elles agissent alternativement ou simultanément.

Ces causes sont attribuables soit au manque d'instruction et d'éducation professionnelles, soit au défaut de concentration des cultures, surtout à l'absence de coopération des producteurs qui ne pouvant ainsi réussir individuellement à uniformiser leurs productions, doivent nécessairement faire de l'horticulture de clocher, c'est-à-dire produire et vendre des produits disparates.

Aussi, l'ensemble de leurs produits ne possédant pas la qualité requise par la demande, et le commerce en gros, qui alimente tous les principaux centres de consommation de la province, leur préférant et leur substituant la production étrangère, il s'ensuit que le volume de la production horticole québecoise se trouve considérablement diminué, et que celle-ci n'obtient que les prix d'occasion du marché de détail.

Qu'il suffise de dire que la génétique n'a pas fait, chez nous, beaucoup de progrès et que c'est à peine si, depuis vingt ans, elle a engendré six nouvelles variétés de mérite.

Voilà l'esquisse du degré d'avancement de l'horticulture québecoise. On peut d'ores et déjà en inférer que son évolution, entravée par les causes indiquées dans notre aperçu général, n'a pas été jusqu'ici assez rapide pour lui permettre de bénéficier pleinement des précieux avantages naturels qu'elle possède sur ses concurrents, et de s'assurer l'entière possession de son marché intérieur qui lui offre les plus prometteuses perspectives.

Et ce qui le prouve bien à l'évidence, ce sont les quantités énormes de produits similaires aux nôtres que les villes de cette province reçoivent constamment de l'extérieur.

(à suivre.)

Reception d'agronomes francais par la section de Montreal

Depuis quelques années c'est la coutume pour les élèves sortant de l'Ecole Nationale d'Agriculture de Grignon, en France, d'aller faire un voyage d'étude à l'étranger et de compléter par l'observation directe de ce qu'on fait et pense ailleurs l'excellente éducation qu'ils ont reçue à l'Ecole. C'est une habitude des plus louables dont on ne saurait trop féliciter l'Ecole de Grignon. Les élèves sortis cette année pour la première fois ont décidé de passer l'Océan et de faire leur voyage d'étude au Canada. C'est ainsi qu'un groupe d'une vingtaine de jeunes ingénieurs agricoles français est arrivé à Québec au début du mois d'août sous la conduite de quatre professeurs de l'Ecole de Grignon: MM. Henri Mamelle, directeur de la mission, Benoit Rambaud, Jean Guérillot et Paul Verchère.

L'initiativé des Grignonnais de cette année est d'autant plus digne d'être signalée qu'en raison notamment des conditions du change l'organisation d'un voyage au continent américain présente pour des professeurs et étudiants d'Europe des difficultés financières sérieuses. La Mission d'Etude put heureusement trouver un appui auprès du Comité France Amérique, sous les auspices duquel le voyage fut organisé, et qui entreprit de régler les détails de la visite.

Les techniciens agricoles de tout le Dominion, et plus particulièrement peut-être ceux de la Province de Québec, par l'entremise de leur association, la Société des Agronomes, eussent été heureux d'être les guides de leurs confrères de France dans leur visite du Canada agricole, et regrettent certes que le comité d'organisation ne se soit pas adressé à eux dans ce but. M. A. A. Gardiner, agent général des passagers aux Chemins de Fer Canadiens Nationnaux, qui accompagnait la Mission d'Etude, ayant en cependant l'heureuse idée d'emmener les visiteurs à Ste. Martine, dans le comté de Châteauguay, dont l'agronome est M. P. N. April, président de la section de Montréal de la C.S.T.A., celui-ci put quand même organiser un dîner en l'honneur de la mission d'étude et convoquer les membres de la section de Montréal à venir rencontrer les visiteurs.

La réception eut lieu le 15 août dans les locaux de l'Ecole Ménagère de Ste. Martine, après la visite de deux fermes canadiennes-françaises typiques du comté de Châteauguay. Pour peut-être pas tout-à-fait aussi officielle qu'elle eût pu l'être, la réception ne perdit rien de sa signification et de sa dignité, et la plus franche cordialité ne cessa de régner entre les agronomes de France et leurs confrères du Canada. Tour à tour, M. April, Mgr. Allard,curé de Ste Martine, et l'Hon. M. Mercier, Ministre des Terres et Forêts, souhaitèrent la bienvenue aux visiteurs. Puisqu' "en France tout se termine par des chansons" il était inévitable que des chansons fussent échangées: M. Elie, maître de chapelle à Ste Martine, fit entendre des mélodies françaises et canadiennes, puis le choeur des Grignonnais fit retentir les mâles refrains de l'Ecole de Grignon. D'une voix émue, M. Mafelle remercia les hôtes de la Mission, et les convives se dispersèrent après le chant de "la Marseillaise" et de "O Canada",....pour reprendre pendant longtemps dans les couloirs de l'Ecole Ménagère les conversations interrompues.

H.E.L.

CONCERNING THE C.S.T.A.

Notes and News

J. Coke (Toronto '16), Associate Professor of Agricultural Economics at the Ontario Agricultural College, and W. Allen (Saskatchewan '22), Professor of Farm Management at the University of Saskatchewan, are attending a conference of agricultural economists which is being held at Dartington Hall, Totnes, Devon, England. Dartington Hall is the estate of Leonard K. Elmhirst, a graduate of Cambridge and Cornell Universities, who has provided a number of fellowships, enabling representatives from America and Europe to attend this conference.

M. B. Davis (McGill '12), Chief Assistant, Division of Horticulture, Central Experimental Farm, Ottawa, has been granted a year's leave of absence for the purpose of taking a course of special studies at the Research Station, Long Ashton, Bristol, England.

L. C. Roy (McGill '17), for the past four years District Inspector of County Agriculturists with the Quebec Department of Agriculture, has received the appointment of Special Agricultural Agent for Quebec for the Canadian National Railways. He will be attached to the Department of Colonization and Agriculture of the C.N.R., with headquarters at Montreal, P.Q.

T. H. Mason, after twenty-two years' service in the Dominion Department of Agriculture, has retired from the position of Inspector of Live Stock Pedigrees under the Dominion Live Stock Branch, which he has held since 1912. Mr. Mason was one of the first class of students to enter the Ontario Agricultural College and he received the Associate Diploma of that institution in 1876. His address is 49 Patterson Avenue, Ottawa, Ontario.

W. H. Upshall (Toronto '23), Research Specialist at the Horticultural Experiment Station, Vineland, Ont., has received the Ph.D. degree from the University of Maryland.

F. G. North (Toronto '23) has joined the staff of Stinson-Reeb Builders Supplies Ltd., 360 Dorchester Street West, Montreal, P.Q. He has charge of the Peat and Moss Department of the Company.

G. A. Scott (Toronto '23) has changed his address to Williamstown, Ontario.

A. D. Campbell (Toronto '09) is now connected with the United Dairies Limited of Calgary. He is Manager of the Central Dairy Cattle Co. Ltd., 602-3rd Avenue West, Calgary, Alta.

A. P. Pelletier (Laval '20) County Agriculturist for Montmorency County, P.Q., has changed his mailing address to L'Ange-Gardien, P.Q.

T. S. Acheson, formerly General Agricultural Agent for the Canadian Pacific Railway, is now in charge of the Agricultural Department of James Richardson & Sons, Ltd., Winnipeg, Man.

L. D. Mallory (British Columbia '27) is taking graduate work towards a Ph.D. degree in agricultural economics and marketing at the University of California. His mailing address is 328 Hilgard Hall, University of California, Berkeley, Cal., U.S.A.

Victor E. Graham (Saskatchewan '27), who is taking graduate work towards a Ph.D. degree in dairy bacteriology at the University of Wisconsin, is at present at Flathead Lake, Montana, doing bacteriological work, with a biological party from the State University. His temporary address is Biological Station, Polson, Montana, U.S.A., and after his return to the University his address will be 726 University Avenue, Madison, Wis., U.S.A.

E. K. Williams (McGill '23) has accepted a position as Equipment Engineer with the Northern Electric Company, Montreal. He takes up his new duties on September 3rd, and his mailing address is 460 Bloomfield Avenue, Outremont, P.Q.

I. L. Conners (McMaster '18), formerly Plant Pathologist under the Dominion Botany Division at Brandon, Man., and Winnipeg, Man., is now at the Central Experimental Farm, Ottawa, Ont.

F. L. Drayton (McGill '14), Plant Pathologist at the Central Experimental Farm, Ottawa, is continuing graduate work towards his Ph.D. at Cornell University. His mailing address is 318 Elmwood Avenue, Ithaca, N.Y., U.S.A.

E. D. McGreer (McGill '22), who for the past year has been Associate Editor of the *Ontario Farmer,* has joined the editorial staff of the *Farm and Ranch Review,* Calgary, Alberta.

S. H. Vigor (Saskatchewan '20), for the past year Acting Field Crops Commissioner for the Saskatchewan Department of Agriculture, has received the appointment of Field Crops Commissioner.

Applications for Membership

The following applications for regular membership have been received since August 1, 1929:—

Armstrong, John M. (Saskatchewan, 1929, B.Sc.) Saskatoon, Sask.

Machacek, J. E. (Saskatchewan, 1924, M.S.A., McGill, 1928, Ph.D.) Macdonald College, P.Q.

Maltais, J. B. (Laval, 1923, B.S.A., McGill, 1928, M.Sc.), Hemmingford, P.Q.

Marshall, James (Washington State, 1929, M.Sc.) Annapolis Royal, N.S.